CHARACTERISTICS OF MAJOR ACTIVE WIND TUNNELS AT THE LANGLEY RESEARCH CENTER

By William T. Schaefer, Jr.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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SUMMARY

This report contains a brief description of each of the major active wind tunnels at the Langley Research Center. An illustration of each facility is provided.

INTRODUCTION

The information contained in this report is compiled in response to a recognized need for such information by the aerospace industry and other government agencies concerned with aerospace research. The Langley research division responsible for each tunnel is designated in this document together with the building in which the facility is located, a descriptive illustration of the facility, and pertinent data. The tunnel descriptions are presented in the order of tunnel size, the smallest tunnel appearing first. Users of this report are cautioned that some of the information will invariably become outdated as the tunnels are modified.

Several Langley tunnels have unusual environmental characteristics which are discussed in reference 1. Reference 2 is a compilation of the characteristics of all major wind tunnels in the United States. Reference 3 is a manual for users of the three NASA Unitary Plan wind-tunnel facilities and provides detailed descriptions of the facilities, information regarding the operating characteristics of each tunnel, and preliminary information concerning model design.

USE OF FACILITIES

The primary objective of NASA wind tunnels is to support NASA-sponsored research and development programs; however, testing time in NASA tunnels may be made available upon specific request for two types of non-NASA projects:

(1) Government projects - projects that are conducted under contract with, supported by, or of vital concern to a Government agency.

(2) Company projects - proprietary tests that may be conducted on a fee basis, primarily in the NASA Unitary Plan wind tunnels.

It is the policy of the National Aeronautics and Space Administration in undertaking such requested testing not to compete with commercially available facilities. With the exception of the Unitary Plan wind tunnels, NASA research tunnels may be assigned to company projects only in unusual cases. Company projects are conducted in the NASA Unitary Plan wind tunnels when they are clearly in the national interest.

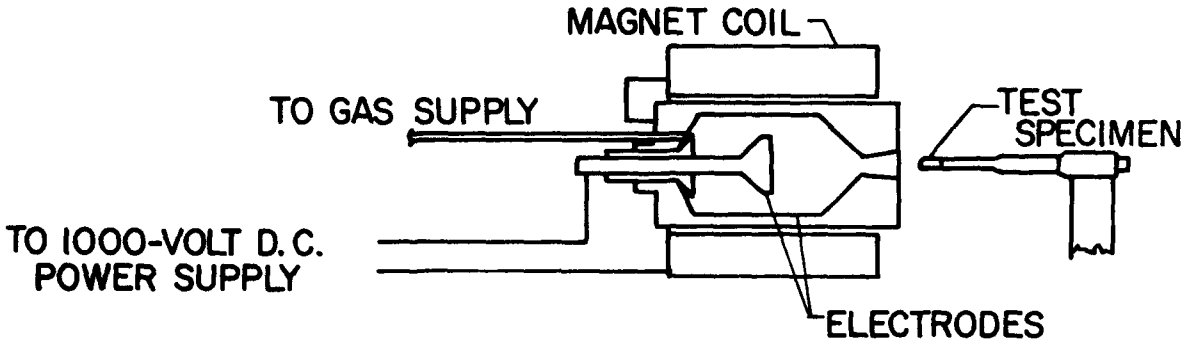
Prior to the submission of a formal request for tests in Langley Research Center tunnels, the interested organization should confer with the staff of the facility involved to review the nature of the required tests, to determine the compatibility of the facility to conduct the proposed tests, and to explore the possibility of testing time being made available. Formal requests for tests in Langley tunnels should be addressed to

Associate Administrator
Office of Advanced Research and Technology
National Aeronautics and Space Administration
Washington, D.C. 20546

Each request is considered upon its individual merit in the national interest. The requesting organization is advised in writing whether the tests can be undertaken. Details regarding the scheduling and conduct of the tests are negotiated directly with the Langley Research Center.

Requests from the U.S. Navy, U.S. Air Force, and U.S. Army are coordinated by two NASA allocation and priority groups, one for aircraft and missile projects and one for propulsion projects. Each group is comprised of one member each from the NASA, the Navy, the Air Force, and the Army. Requests from the military contractors are processed through the appropriate military member of the pertinent allocation and priority group.

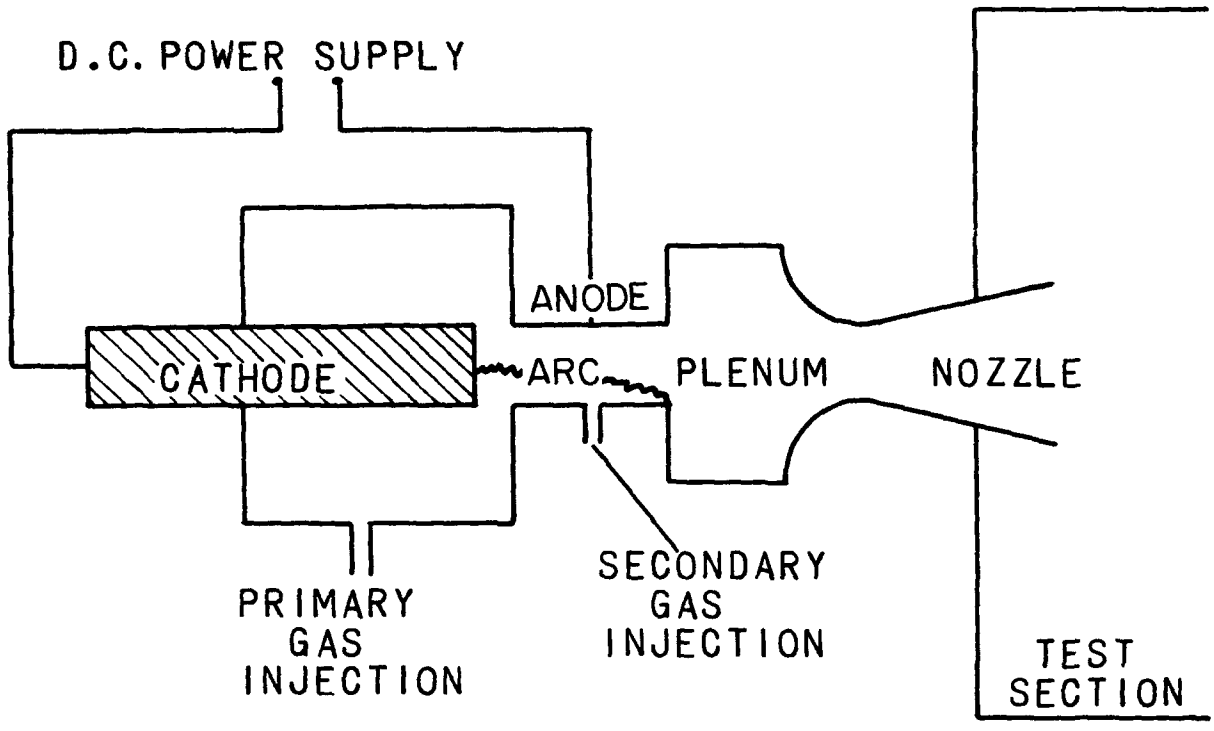
LANGLEY ARC-HEATED MATERIALS JET



The Langley arc-heated materials jet is located in Building 1275 and is under the direction of the Applied Materials and Physics Division. It is used for studies of aerodynamic effects on materials at supersonic velocities and high temperatures. The test medium is nitrogen or air or a combination of these gases. This facility has a swing-arm type of model-insert mechanism. Gases are heated by a magnetically stabilized dc electric arc and expanded to atmospheric pressure through a conical nozzle with a 0.75-inch-diameter exit. Electrodes and nozzle are fabricated of copper and are water cooled. Approximate operating conditions are as follows:

Mach number	2
Stagnation pressure, psia	165
Stagnation enthalpy, Btu/lb	1300

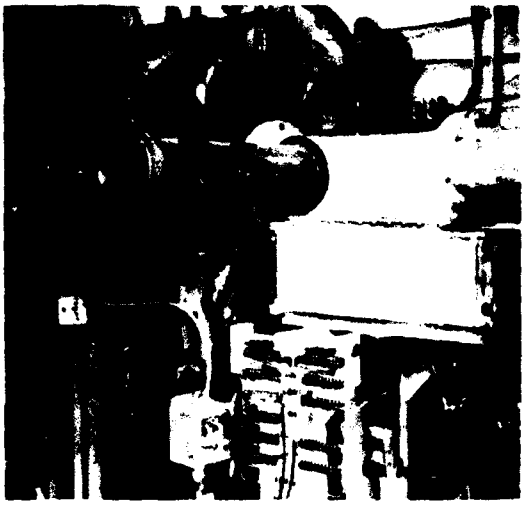
LANGLEY HIGH-ENTHALPY DIRECT-CURRENT PLASMA GENERATOR



The Langley high-enthalpy direct-current plasma generator is located in Building 1267 and is under the direction of the Structures Research Division. The facility is used for materials testing and plasma diagnostics. The test medium is nitrogen; oxygen and/or carbon dioxide can be added. The heat is supplied by a dc constricted arc using tungsten-copper electrodes. Model mounting consists of a water-cooled sting. The facility has a subsonic nozzle with a 1-inch-diameter throat exhausting into the atmosphere and a 1-inch-diameter open-jet test section. Operating conditions may be varied between the test conditions given in the following table which are obtained with nitrogen as the test medium:

Stagnation pressure, psia	17.3	17.7
Stagnation temperature, ^{o}R	15 000	8300
Enthalpy, Btu/lb	17 500	4000
Mach number	0.48	0.54
Velocity, fps	3880	2240
Static pressure, psia	14.7	14.7
Static temperature, ^{o}R	14 700	8200
Static density, slug/cu ft	0.43×10^{-7}	1.24×10^{-7}
Dynamic pressure, lb/sq ft	330	320
Reynolds number per foot	0.44×10^{6}	0.085×10^{6}
Weight flow, lb/sec	0.03	0.06
Running time	Continuous	Continuous

LANGLEY 2-INCH SUPERSONIC ARC JET

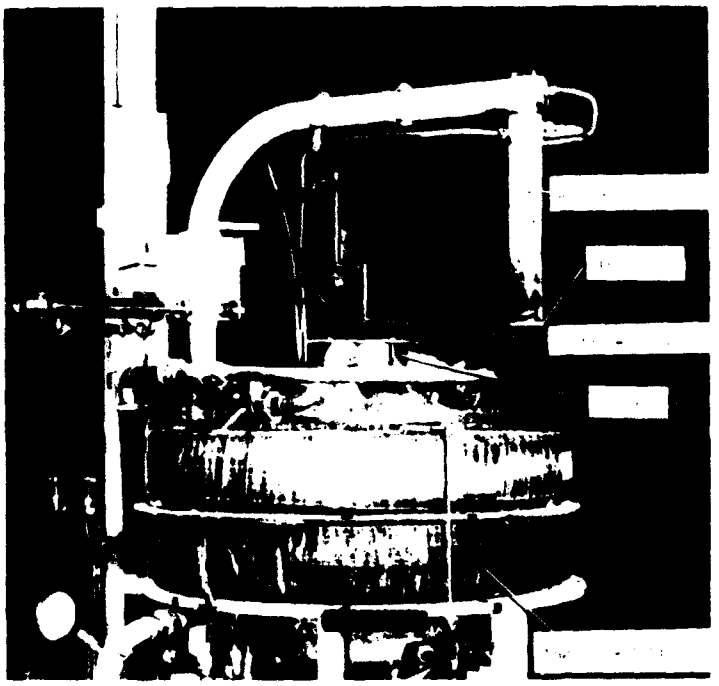


L-65-156

The Langley 2-inch supersonic arc jet is located in Building 1267 and is under the direction of the Structures Research Division. The facility is used for ablation and shear tests of materials. The test medium is air, nitrogen, or mixtures and is heated by ac arc water-cooled copper electrodes. Model mounting consists of a retractable sting. The supersonic conical nozzle has a 1.039-inch-diameter throat and a 2.00-inch-diameter test section. It exhausts with induction nozzle through diffuser into atmosphere. Maximum model diameter is approximately 1 inch. Operating conditions may be varied between the three test conditions given in the following table which are obtained with air as the test medium:

Stagnation pressure, psia	75	75	36.8
Stagnation temperature, ^{o}R . . .	6800	2340	8450
Enthalpy, Btu/lb	2600	600	4000
Mach number	2.50	2.70	2.50
Velocity, fps	8470	3340	9000
Static pressure, psia	4.20	2.65	1.98
Static temperature, ^{o}R	4560	1000	5600
Static density, slug/cu ft . . .	0.65×10^{-4}	2.20×10^{-4}	0.27×10^{-4}
Dynamic pressure, lb/sq ft . . .	2320	2120	1050
Reynolds number per foot	0.340×10^{6}	0.605×10^{6}	0.150×10^{6}
Weight flow, lb/sec	0.35	0.662	0.150
Running time, sec	300	300	300

LANGLEY 2500-KILOWATT ARC JET (1148)

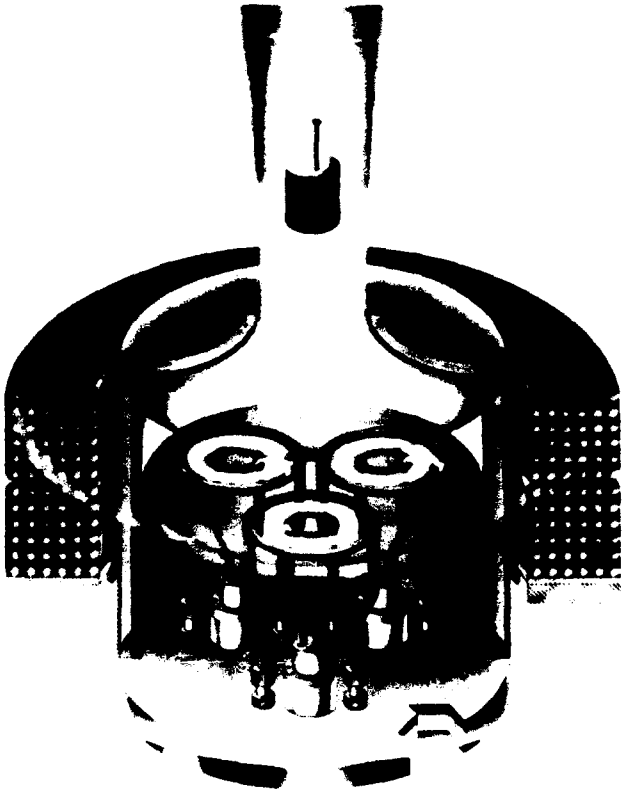


L-61-3423.1

The Langley 2500-kilowatt arc jet is located in Building 1148 and is under the direction of the Structures Research Division. It is used for materials tests. The test medium is air, nitrogen, or mixtures and is heated by ac arc-cooled metallic electrodes. Model mounting consists of a water-cooled retractable sting. Subsonic nozzles exhaust into the atmosphere. Maximum temperature operating conditions for two nozzles available are given in the following table and were obtained using air as the test medium:

Stagnation pressure, psia	15.2	14.8
Stagnation temperature, $^{\circ}R$	7560	7560
Enthalpy, Btu/lb	3550	3550
Nozzle throat diameter, in.	4.0	6.0
Test-section diameter, in.	4.0	6.0
Maximum model diameter, in.	3.0	3.0
Mach number	0.21	0.09
Velocity, fps	890	395
Static pressure, psia	14.7	14.7
Static temperature, $^{\circ}R$	7450	7450
Static density, slug/cu ft	1.4×10^{-4}	1.4×10^{-4}
Dynamic pressure, lb/sq ft	55.7	10.9
Reynolds number per foot	0.066×10^{6}	0.029×10^{6}
Weight flow, lb/sec	0.35	0.35
Running time, sec	600	600

LANGLEY 2500-KILOWATT ARC JET (1267)

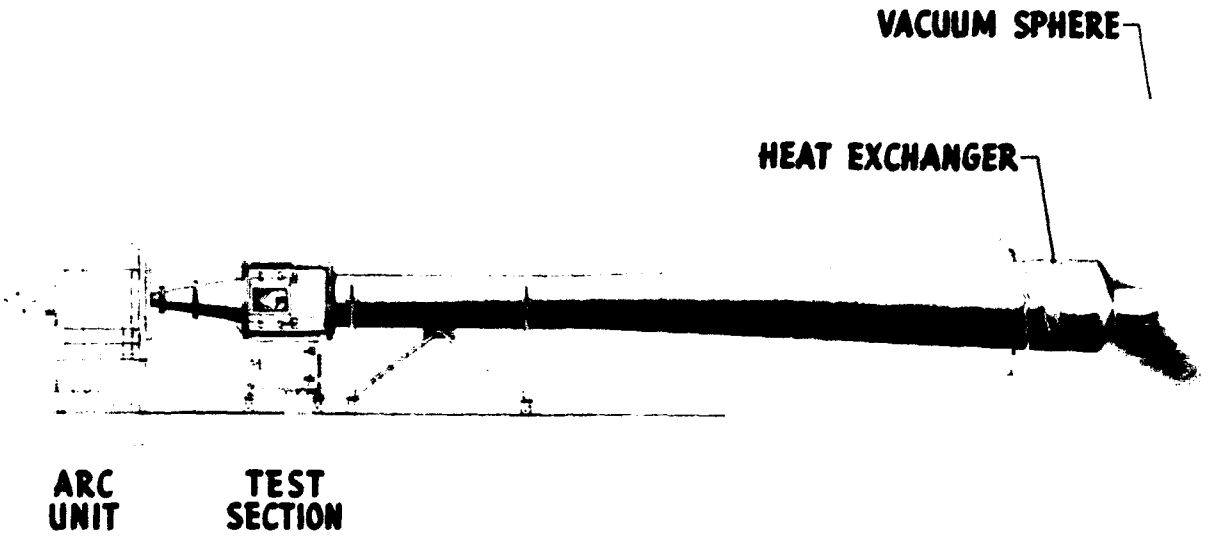


L-1220

The Langley 2500-kilowatt arc jet is located in Building 1267 and is under the direction of the Structures Research Division. This facility is used for materials tests with the test medium being air, nitrogen, or mixtures. The heat is supplied by ac arc-cooled metallic electrodes. Model mounting consists of a water-cooled retractable sting. Nozzles provide closed test sections and exhaust into the atmosphere. Maximum temperature operating conditions for five nozzles available are given in the following table for air as the test medium:

Stagnation pressure, psia	75	35.4	20.4	15.2	14.8
Stagnation temperature, $^{\circ}R$	6800	6800	7560	7560	7560
Enthalpy, Btu/lb	2600	2750	3550	3550	3550
Nozzle throat diameter, in.	1.00	1.50	2.0	4.0	6.0
Test-section diameter, in.	1.25	1.55	2.0	4.0	6.0
Maximum model diameter, in.	1.0	3.0	3.0	3.0	3.0
Mach number	1.7	1.0	0.72	0.21	0.09
Velocity, fps	5500	3600	3000	890	395
Static pressure, psia	15.0	14.7	14.7	14.7	14.7
Static temperature, $^{\circ}R$	5500	6120	7260	7450	7450
Static density, slug/cu ft	2.2×10^{-4}	1.9×10^{-4}	1.4×10^{-4}	1.4×10^{-4}	1.4×10^{-4}
Dynamic pressure, lb/sq ft	4330	1930	920	55.7	10.9
Reynolds number per foot	0.79×10^{6}	0.51×10^{6}	0.25×10^{6}	0.066×10^{6}	0.029×10^{6}
Weight flow, lb/sec	0.35	0.35	0.35	0.35	0.35
Running time, sec	600	600	600	600	600

LANGLEY 10-MEGAWATT ARC TUNNEL



L-997

The Langley 10-megawatt arc tunnel is located in Building 1267 and is under the direction of the Structures Research Division. The tunnel is used for testing ablation, thermal protection, models. The test medium is air and is heated by ac arc water-cooled copper electrodes. Model mounting consists of a retractable sting. The supersonic conical nozzle has a 0.620-inch-diameter throat. The test section is 6.30 inches. The tunnel exhausts through a diffuser and heat exchanger into a vacuum tank at minimum pressure of 1 mm Hg. Operating conditions may be varied between the following test conditions:

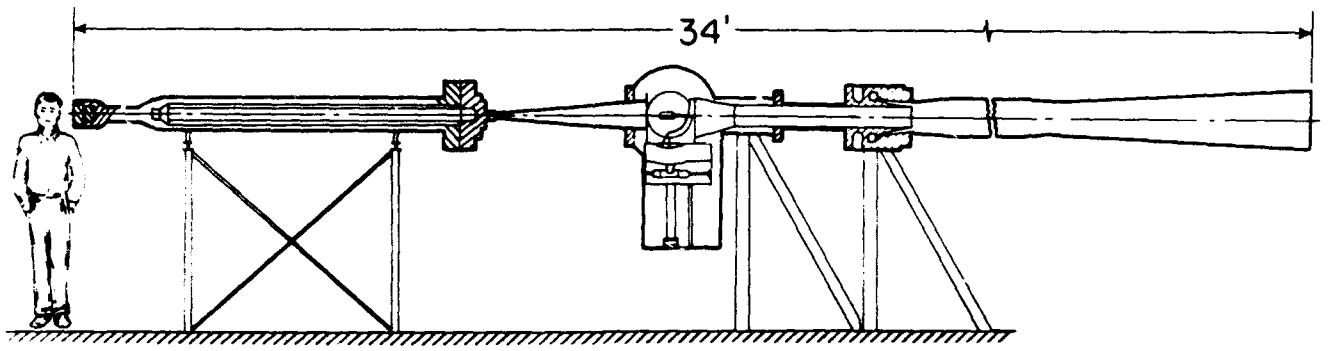
Stagnation pressure, psia	75	345
Stagnation temperature, ^{o}R	7350	2160
Enthalpy, Btu/lb	3000	550
Mach number	5.1	6.85
Velocity, fps	11 000	5100
Static pressure, psia	0.043	0.09
Static temperature, ^{o}R	2100	225
Static density, slug/cu ft	0.018×10^{-4}	0.331×10^{-4}
Dynamic pressure, lb/sq ft	95	462
Reynolds number per foot	0.063×10^{6}	0.46×10^{6}
Weight flow, lb/sec	0.127	1.12
Running time, sec	600	600
Maximum model diameter, in.	3.0	3.0

The Langley 10-megawatt arc tunnel (revised arc chamber) is used for materials and structures testing. The test medium is air heated by dc arc tungsten

electrodes. Model mounting consists of a water-cooled retractable sting. Supersonic conical nozzle has a 0.385-inch-diameter throat and the test section is 6.30 inches. The tunnel exhausts through a diffuser and heat exchanger into a vacuum tank at minimum pressure of 1 mm Hg. Operating conditions may be varied between the following test conditions:

Stagnation pressure, psia	500	500
Stagnation temperature, ^{o}R	15 650	9360
Enthalpy, Btu/lb	12 000	4000
Mach number	5.0	5.5
Velocity, fps	20 500	13 100
Static pressure, psia	0.14	0.079
Static temperature, ^{o}R	6700	2330
Static density, slug/cu ft	0.0143×10^{-4}	0.0287×10^{-4}
Dynamic pressure, lb/sq ft	324	247
Reynolds number per foot	0.15×10^{6}	0.35×10^{6}
Weight flow, lb/sec	0.181	0.286
Running time, sec	600	600
Maximum model diameter, in.	3.0	3.0

LANGLEY 7-INCH MACH 7 PILOT TUNNEL

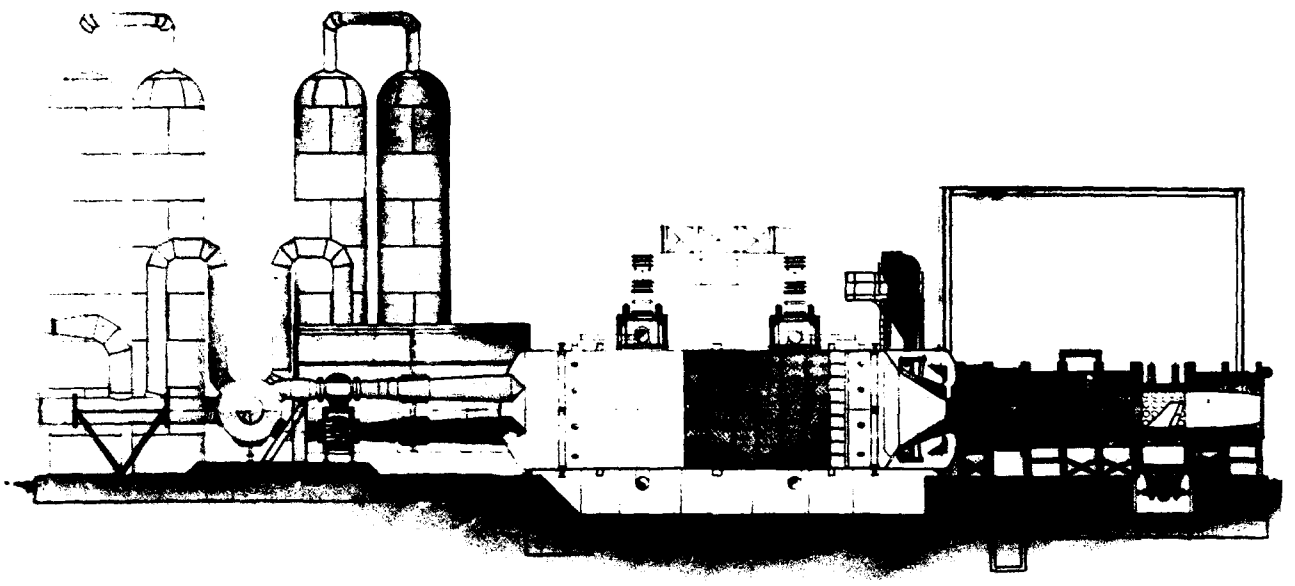


L-1228

The Langley 7-inch Mach 7 pilot tunnel is located in Building 1264 and is under the direction of the Structures Research Division. It is used for heat studies, ablation and development of techniques. The test medium is methane-air combustion. Model mounting consists of sting supports. The tunnel has an axisymmetric, fixed geometry nozzle with a 0.5-inch-diameter test section which exhausts through a diffuser into the atmosphere and has a single-stage annular ejector. Examples of operating conditions are given in the following table:

Stagnation pressure, psia	400	400	2500	2500
Stagnation temperature, ^{o}R	2500	3800	2500	3800
Enthalpy, Btu/lb	700	1140	700	1140
Mach number	7.7	6.5	7.65	6.80
Velocity, fps	5630	7350	5620	7400
Static pressure, psia	0.0364	0.0809	0.243	0.363
Static temperature, ^{o}R	216	515	220	470
Static density, slug/cu ft	0.135×10^{-4}	0.125×10^{-4}	0.89×10^{-4}	0.61×10^{-4}
Dynamic pressure, lb/sq ft	218	340	1425	1664
Reynolds number per foot	0.55×10^{6}	0.29×10^{6}	3.3×10^{6}	1.5×10^{6}
Weight flow, lb/sec	0.3	0.3	1.3	1.3
Running time, sec	70	70	150	150
Maximum model diameter, in., for -				
Blunt body	2	2	2	2
Streamlined body	3.25	3.25	3.25	3.25

LANGLEY 9- BY 6-INCH MODEL TUNNEL

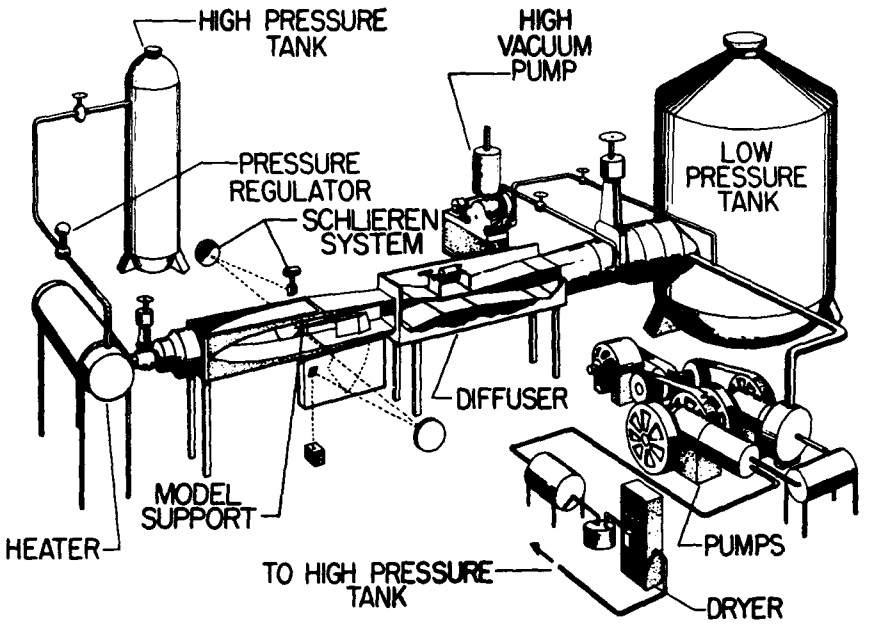


L-331

The Langley 9- by 6-inch model tunnel is located in Building 1256 and is under the direction of the Structures Research Division. The tunnel is used for blockage studies, and the test medium is air. Model mounting consists of sting or floor. The nozzle is a supersonic two-dimensional one with a throat size of 8.75 by 1.38 inches. The test section is 8.75 by 6.00 inches and exhausts through a diffuser into the atmosphere. Examples of operating conditions are as follows:

Stagnation pressure, psia	50	125	200
Stagnation temperature, ^{o}R . . .	520	520	520
Enthalpy, Btu/lb	130	130	130
Mach number	3.0	3.0	3.0
Velocity, fps	2000	2000	2000
Static pressure, psia	1.36	3.40	5.44
Static temperature, ^{o}R	185	185	185
Static density, slug/cu ft	6.18×10^{-4}	15.45×10^{-4}	24.75×10^{-4}
Dynamic pressure, lb/sq ft	1230	3080	4950
Reynolds number per foot	8.5×10^{6}	21.0×10^{6}	33.8×10^{6}
Weight flow, lb/sec	14.1	35.2	56.4
Running time, sec	180	180	180
Maximum model diameter, in. . . .	2.85	2.85	2.85

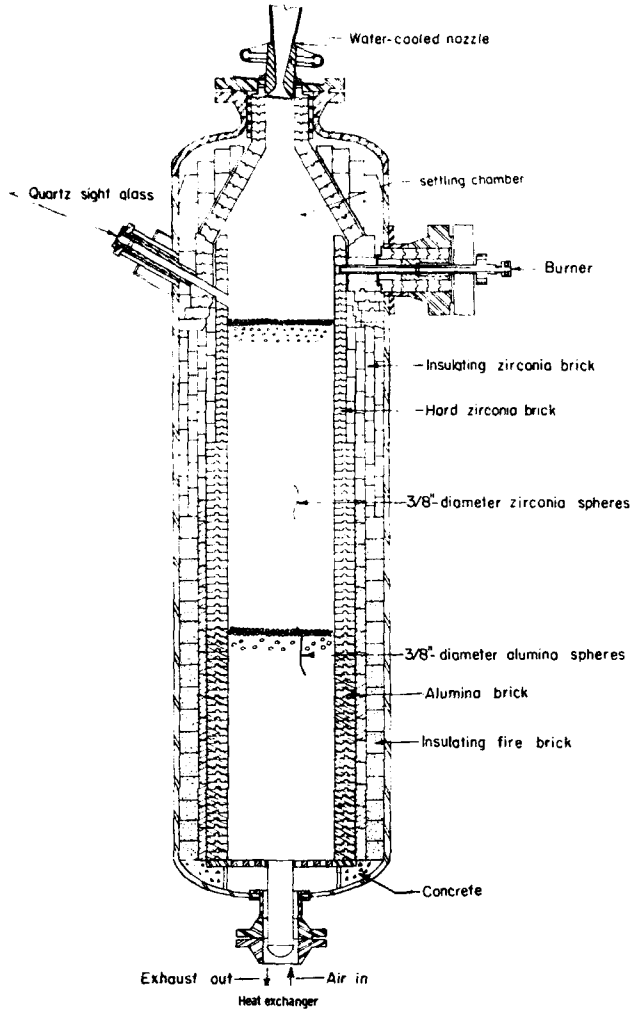
LANGLEY 11-INCH HYPERSONIC TUNNEL

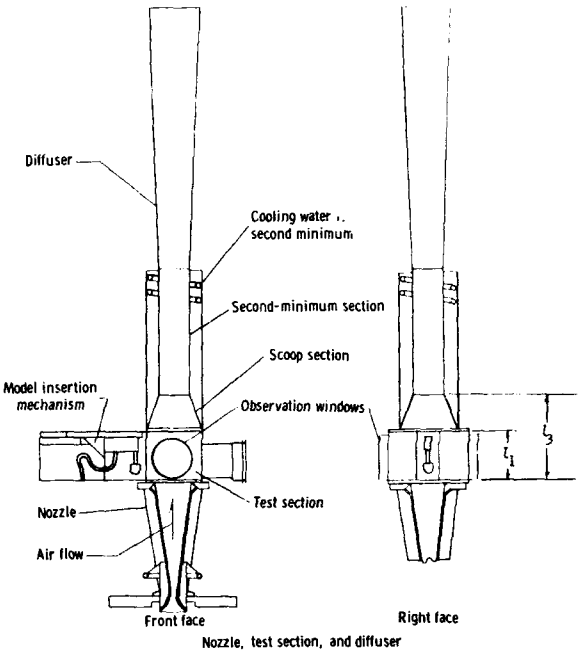


The Langley 11-inch hypersonic tunnel is located in Building 1229 and is under the direction of the Aero-Physics Division. It is used for pressure investigation, heat-transfer studies, and force testing with air and helium as the test media. Air runs are heated by an electrical resistance heater. Model mounting consists of sting and wall mount. There are four interchangeable nozzles: two air and two helium. Mach number 6.8 nozzle is two dimensional, and Mach number 9.6, Mach number 10.5, and Mach number 18.0 nozzles are three dimensional. Operating conditions are given in the following table for each of the nozzles:

Nominal Mach number	6.8	9.6	10.5	18.0
Throat size, in.	0.0915 by 11	0.373 sq.	0.913 (diam.)	0.368 (diam.)
Test medium	Air	Air	Helium	Helium
Stagnation pressure, psia	70 to 540	220 to 690	200 to 800	400 to 1600
Reynolds number per foot	0.5×10^6 to 4.0×10^6	0.3×10^6 to 1.0×10^6	2.7×10^6 to 9.8×10^6	1.2×10^6 to 10.0×10^6
Running time, sec	70 to 100	100	14	10
Core of uniform flow (average), in.	5 by 5	4 by 4	6 (diam.)	4 (diam.)

LANGLEY 11-INCH CERAMIC-HEATED TUNNEL



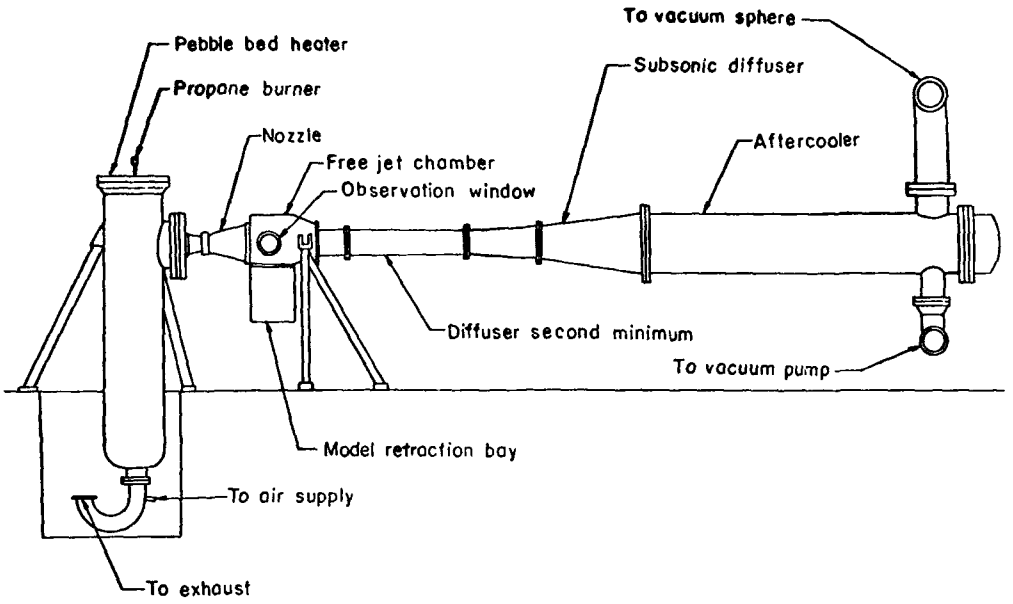


Nozzle, test section, and diffuser

The Langley 11-inch ceramic-heated tunnel is located in Building 1263 and is under the direction of the Applied Materials and Physics Division. The tunnel is used for high-temperature materials research, and the test media are air and nitrogen heated by a zirconia pebble-bed heat exchanger. Model mounting consists of a water-cooled model insertion mechanism to insert and retract the models during a test run. The facility consists of three nozzle systems. The Mach number 2 and Mach number 4 systems are free jets exhausting into the atmosphere. The Mach number 6 system has an open jet test section and diffuser exhausting into the atmosphere. Mach number 2 and Mach number 4 nozzles are contoured nozzles, and Mach number 6 nozzle is a conical nozzle. Operating conditions for the nozzle systems are as follows:

Mach number	2	4	6
Stagnation pressure, psia	115	800 to 1200	700 to 1200
Stagnation temperature, ^{o}R	2400 to 4000	2400 to 4000	2400 to 4000
Nozzle exit diameter, in.	1.30	4.0	10.6

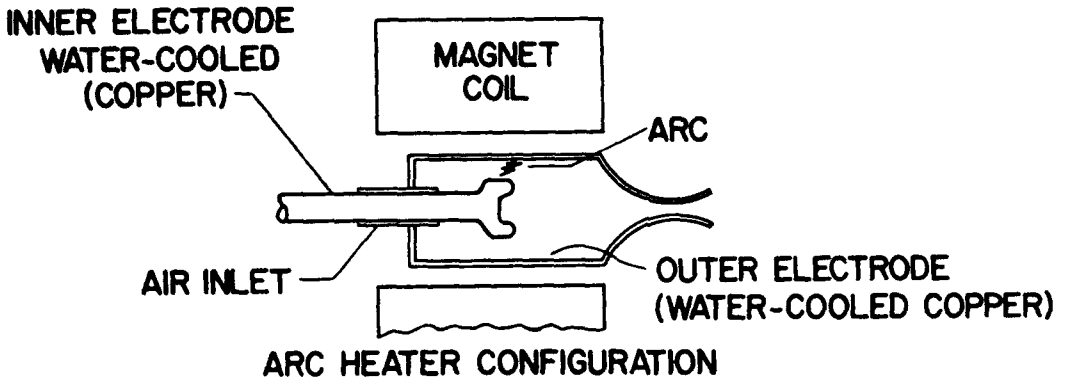
LANGLEY 12-INCH HYPERSONIC CERAMIC-HEATED TUNNEL



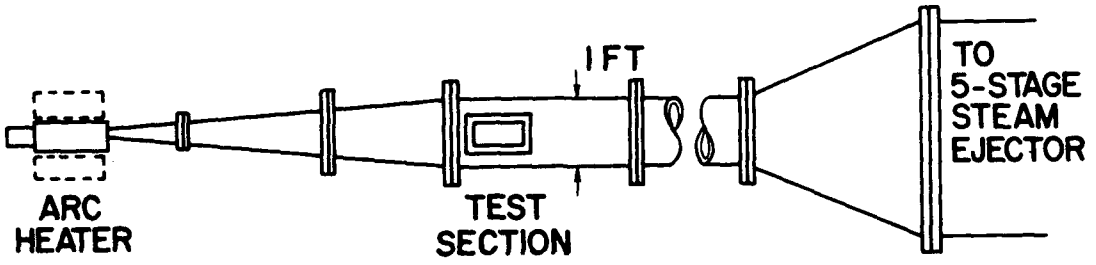
The Langley 12-inch hypersonic ceramic-heated tunnel is located in Building 1274 and is under the direction of the Applied Materials and Physics Division. The tunnel is used for high-temperature materials research and the test medium is air which is heated by a pebble-bed heat exchanger. Model mounting consists of a mechanism which inserts and retracts the model during test runs. The conical nozzle has an 8° half-angle expansion and exit diameter of 12 inches. There is a free jet test section which exhausts through a diffuser into a vacuum sphere. Operating conditions may be varied between the following test conditions:

Stagnation pressure, psia	65 to 600
Stagnation temperature, $^{\circ}R$	2400 to 3700
Mach number	12.5 to 13.6
Velocity, fps	5350 to 6600
Dynamic pressure, lb/sq ft	5 to 33
Reynolds number per foot	0.017×10^6 to 0.230×10^6
Running time, sec	30 to 60
Maximum model size, in.	3.75 hemisphere nose

LANGLEY 1-FOOT HYPERSONIC ARC TUNNEL



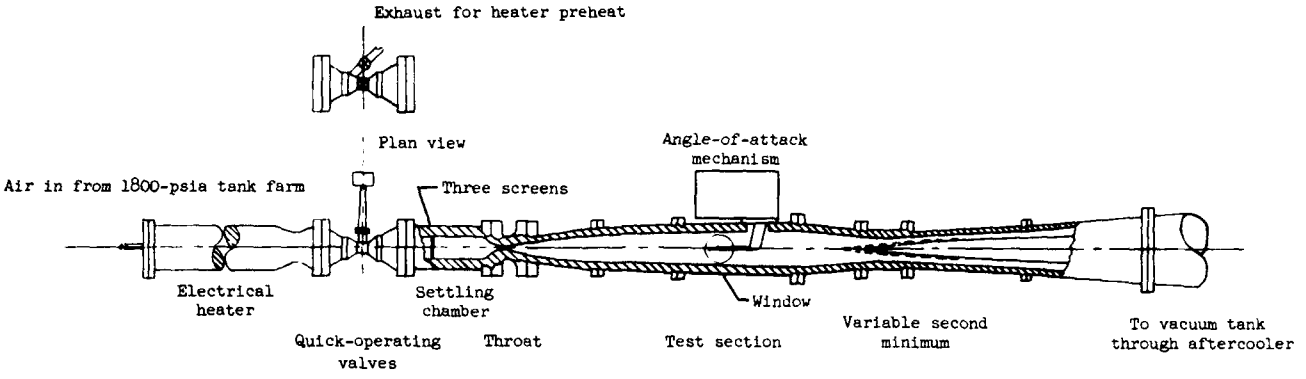
ARC HEATER CONFIGURATION



The Langley 1-foot hypersonic arc tunnel is located in Building 1191 and is under the direction of the Aero-Physics Division. This tunnel is used for high-enthalpy hypersonic fluid-mechanics research, and the test medium is air which is heated by 1.5 megawatt dc arc heater. Model mounting consists of fixed supports from tunnel sides and floor. The tunnel has a conical nozzle with 0.125-inch-diameter or 0.133-inch-diameter throat and exhausts through a steam ejector into the atmosphere. The diameter of the test section is 1 foot. Test core size is approximately 5.5 inches. Operating conditions are as follows:

Stagnation pressure, psia	220 to 400
Stagnation temperature, ^{o}R	7000
Enthalpy, Btu/lb	1500 to 3000
Mach number	12
Reynolds number per foot	0.01×10^6 to 0.02×10^6
Running time, sec	60 to 900
Maximum model size	
Blunt models	2 in. in diameter
Slender models	1 ft long

LANGLEY HYPERSONIC FLOW APPARATUS



The Langley hypersonic flow apparatus is located in Building 583 and is under the direction of the Full-Scale Research Division. This facility is used for force, pressure, heat transfer, and flutter testing. The test medium is air heated by a 2000-kVA dc resistance heat exchanger. Model mounting consists of sting and circular-arc strut. Side-wall model mounting is possible by replacing the schlieren window. Contoured axially symmetric nozzle is 0.513 inch in diameter, test section is 15 inches in diameter, and test core is 10 inches in diameter. It exhausts into a vacuum tank. Examples of operating conditions are as follows:

Stagnation pressure, psia	800 to 1200
Stagnation temperature, ^{o}R	1500 to 1760
Enthalpy, Btu/lb	425
Mach number	10.03
Reynolds number per foot	1.3×10^{6} to 2.0×10^{6}
Running time, sec	180

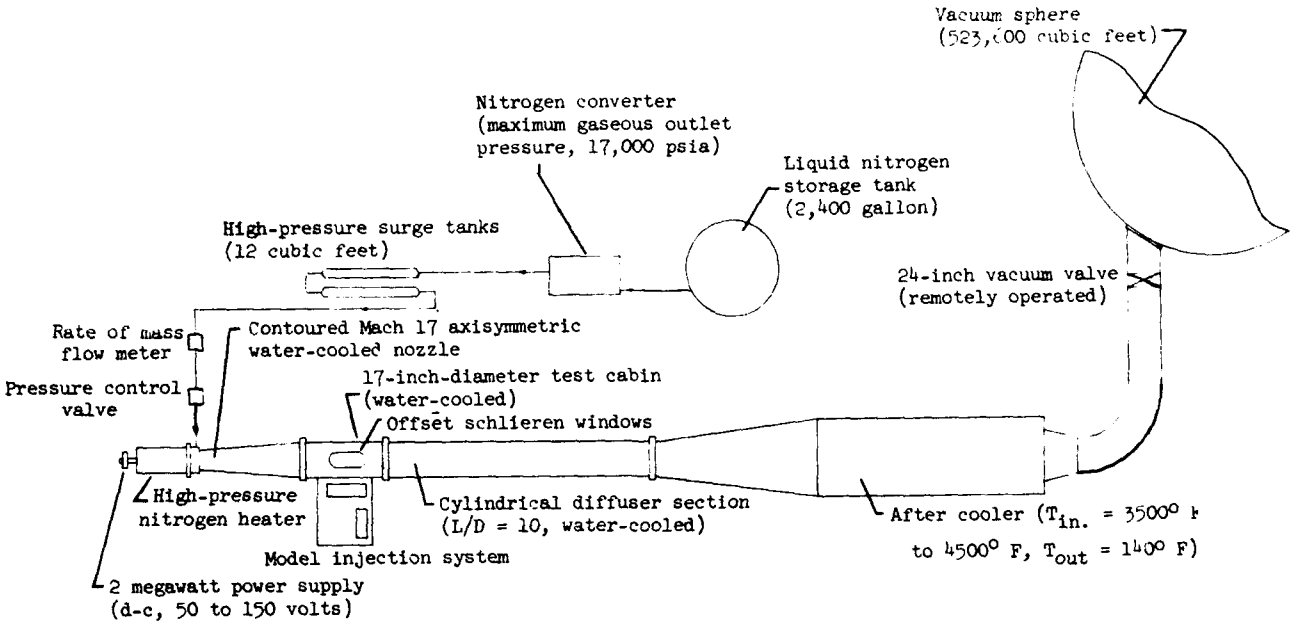
LANGLEY MACH 8 VARIABLE-DENSITY HYPERSONIC TUNNEL

L-61-2866

The Langley Mach 8 variable-density hypersonic tunnel is located in Building 1247D and is under the direction of the Aero-Physics Division. This tunnel is used for fundamental aerodynamic and fluid dynamic investigations over large Reynolds number ranges using pressure and heat-transfer measurements. The test medium is air and is heated by a combination of Dowtherm and electrical resistance. Model mounting consists of sting mount with injection mechanism. The tunnel has an axially symmetric contoured nozzle. The test-section diameter is 18 inches, and the test core size is 4 inches to 14 inches depending on pressure. It exhausts into a vacuum tank or atmosphere. Examples of operating conditions are as follows:

Stagnation pressure, psia	15 to 2930
Stagnation temperature, ^{o}R	1160 to 1510
Mach number	7.5 to 8.0
Reynolds number per foot	0.1×10^6 to 12.0×10^6
Running time, sec, for -	
Exhausting into vacuum tank	90
Exhausting into atmosphere	600

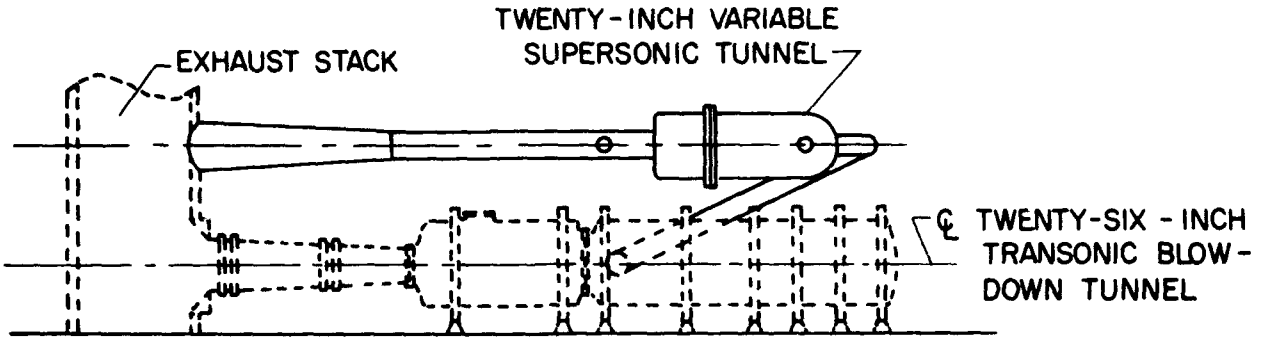
LANGLEY HYPERSONIC NITROGEN TUNNEL



The Langley hypersonic nitrogen tunnel is located in Building 1247B and is under the direction of the Aero-Physics Division. This tunnel is used for heat transfer and force studies with nitrogen as the test medium which is heated by a tungsten grid resistance heater. Model mounting consists of a 2000-psi hydraulic, quick-injection rate system. The tunnel has an axially symmetric contoured nozzle. The test-section diameter is 19 inches and the test core size is approximately 8 inches at high pressure. It exhausts into a 100-foot vacuum sphere. Examples of operating conditions are as follows:

Stagnation pressure, psia	15 000 max.
Stagnation temperature, °R	4460
Mach number	18
Reynolds number per foot	0.155×10^6 to 0.785×10^6
Running time, min	In excess of 30

LANGLEY 20-INCH VARIABLE SUPERSONIC TUNNEL

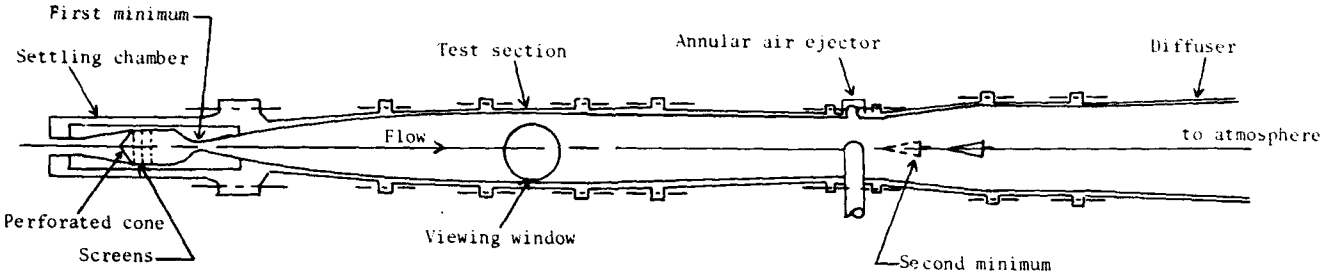


The Langley 20-inch variable supersonic tunnel is located in Building 583 and is under the direction of the Full-Scale Research Division. This tunnel is used for force and pressure tests on configurations, air inlets, jet exits, and boundary layers, and for flutter tests. The test medium is air and is heated by electrical resistance heat exchangers. Model mounting consists of sting and straight through strut, with offset stings for limited extended maximum valves. In addition, side-wall support mounts are available. It has a two-dimensional contoured, variable nozzle with automatic trimming control. The nozzle throat size is 20 inches wide with variable height, the test section is 20 by 20 inches, and test-section core is from 16.06 inches to 17.3 inches wide by 15.46 inches to 16.28 inches high depending on Mach number. It exhausts into the atmosphere. Examples of operating conditions are as follows:

Stagnation pressure, psia	25 to 130
Stagnation temperature, ^{o}R	520 to 660
Enthalpy, Btu/lb	124 to 157
Mach number	2.0 to 4.5
Reynolds number per foot	8.5×10^6 to 20.5×10^6
Running time, sec	40 to 300

LANGLEY 20-INCH HYPERSONIC TUNNELS

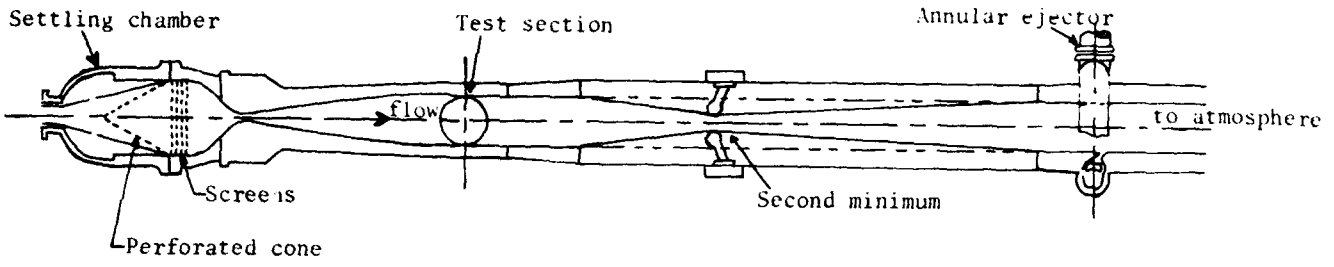
Langley 20-Inch Hypersonic Tunnel (Mach 8.5)



The Langley 20-inch hypersonic tunnel (Mach 8.5) is located in Building 1247D and is under the direction of the Aero-Physics Division. This tunnel is used for heat transfer, pressure, and force testing. The test medium is air and is heated by an electrical resistance heater. Model mounting consists of a sting support and model injection mechanism. It has an axially symmetric contoured nozzle. The test section is 21 inches in diameter, and the test core is 16 inches in diameter. It exhausts through movable second minimum to atmosphere with aid of annular ejector. Examples of operating conditions are as follows:

Stagnation pressure, psia	1600 to 2500
Stagnation temperature, ^{o}R	1510
Mach number	8.5
Reynolds number per foot	4.8×10^6 to 7.5×10^6
Running time (maximum), min	7

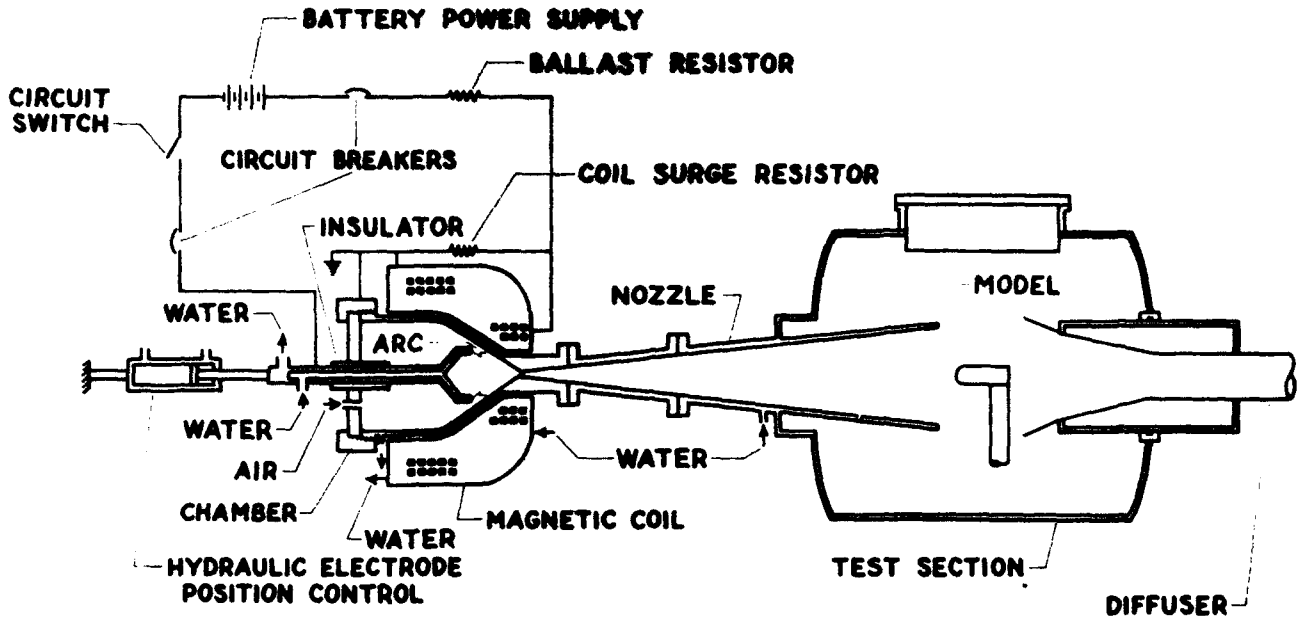
Langley 20-Inch Hypersonic Tunnel (Mach 6)



The Langley 20-inch hypersonic tunnel (Mach 6) is located in Building 1247D and is under the direction of the Aero-Physics Division. This tunnel is used for heat tranfer, pressure, and force testing. The test medium is air and is heated with a Dowtherm heat exchanger. Model mounting consists of a sting support and model injection mechanism. Mach 6 nozzle blocks are two dimensional and contoured. The test section is 20 by 20 inches, and the test core is approximately 16 by 16 inches. It exhausts through a movable second minimum into atmosphere with the aid of an annular ejector. Examples of operating conditions are as follows:

Stagnation pressure, psia	200 to 550
Stagnation temperature, ^{o}R	1000
Mach number	6
Reynolds number per foot	3×10^6 to 10.5×10^6
Running time, min	Over 15

LANGLEY 20-INCH HYPERSONIC ARC-HEATED TUNNEL



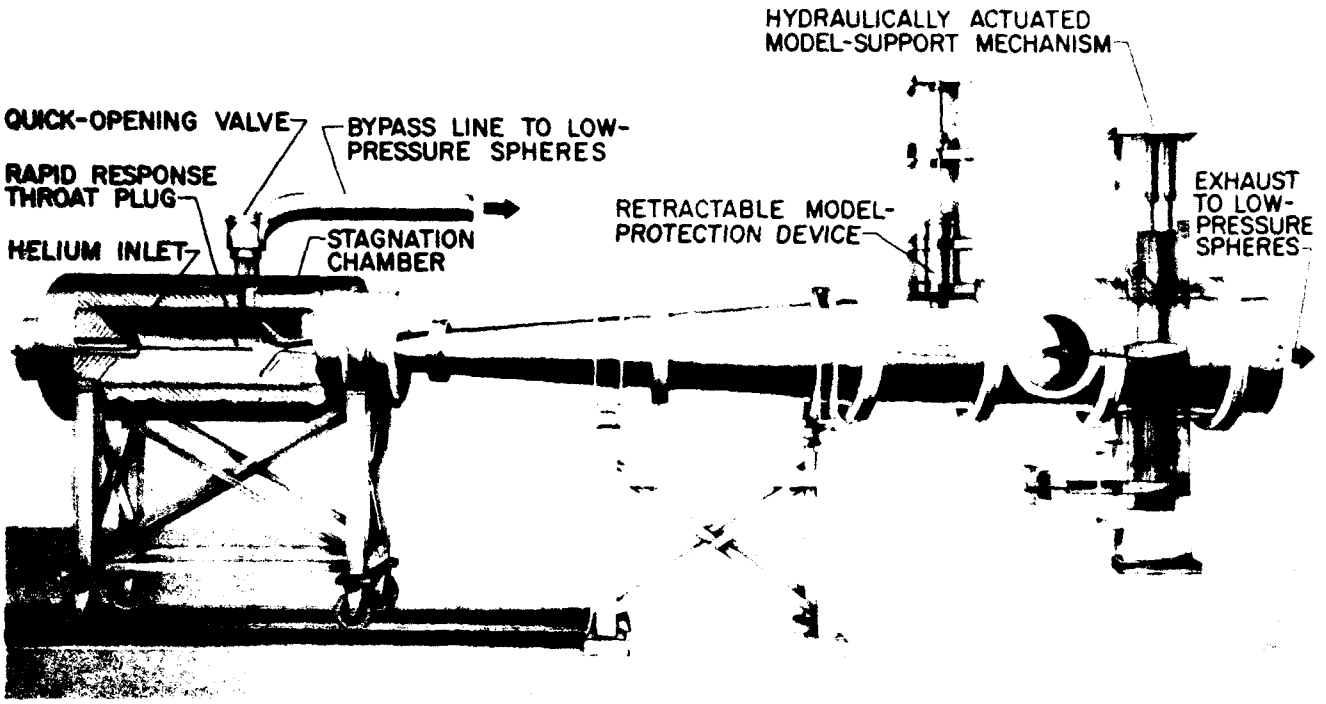
L-1488

The Langley 20-inch hypersonic arc-heated tunnel is located in Building 1275 and is under the direction of the Applied Materials and Physics Division. This tunnel is used for tests of reentry materials. Test media are air and nitrogen, heated by means of an electric arc. Model mounting consists of model insertion equipment. Test conditions can be varied by preselecting values of arc power, total pressure, throat diameter, and nozzle length. Operating conditions used to determine three typical test points are as follows:

Arc power, MW	1.8	1.95	2.06
Stagnation pressure, psia	76	157	389
Mach number	6 or 10	6 or 10	6 or 10
Total enthalpy, Btu/lb	4672	2750	1602

Models up to 2 inches in diameter can be accommodated for the low Mach number test section (M = 6), and models up to 4 inches in diameter can be tested with the use of the high Mach number nozzle (M = 10). Running time with low Mach number nozzles is 180 seconds and running time with high Mach number nozzles is 60 seconds.

LANGLEY 22-INCH HELIUM TUNNEL

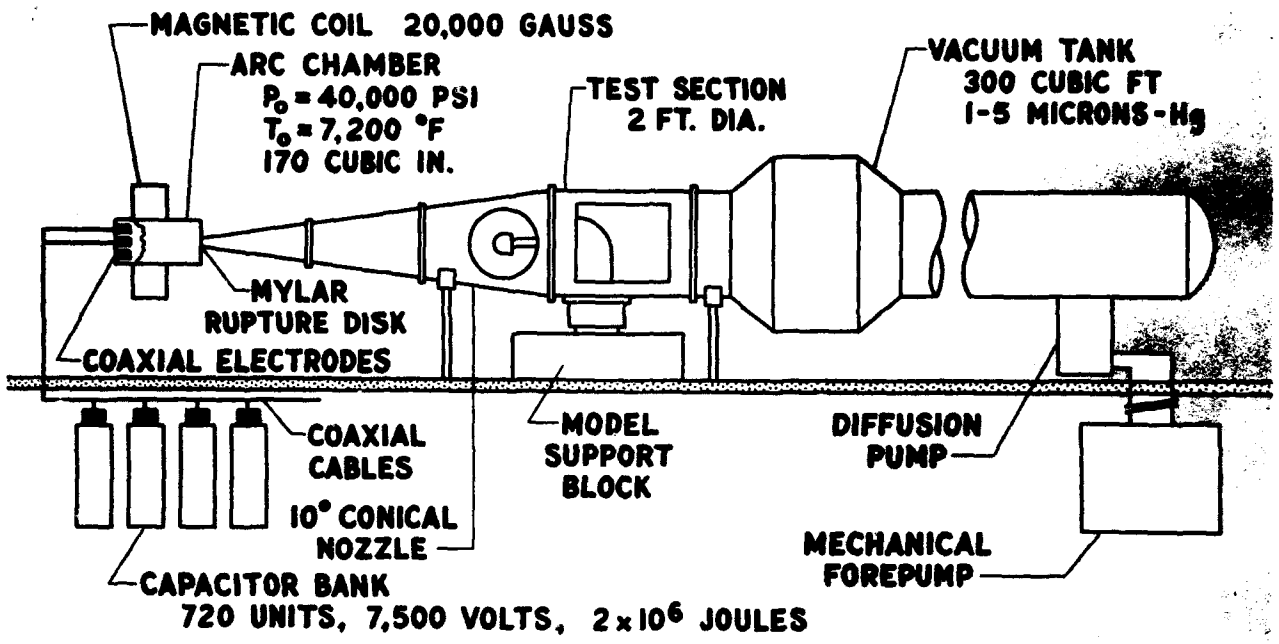


L-1719

The Langley 22-inch helium tunnel is located in Building 1247B and is under the direction of the Aero-Physics Division. This tunnel is used for force, pressure distributions, and heat-transfer tests. The test medium is purified helium. Test medium is supplied at ambient temperature or temperatures up to 400° F through electrical resistance heater. Model mounting consists of a vertical strut. The test section is 22.5 inches in diameter and the test core is 8 inches to 10 inches in diameter and it exhausts into a vacuum tank. Contoured nozzles supply discrete Mach numbers of 18 to 24; however, only the Mach number 20 nozzle has been calibrated. Examples of operating conditions are as follows:

Stagnation pressure, psia	500 to 3600
Mach number	18 to 24
Reynolds number per foot	3×10^6 to 15×10^6
Running time, sec	40 to 60

LANGLEY HOTSHOT TUNNEL

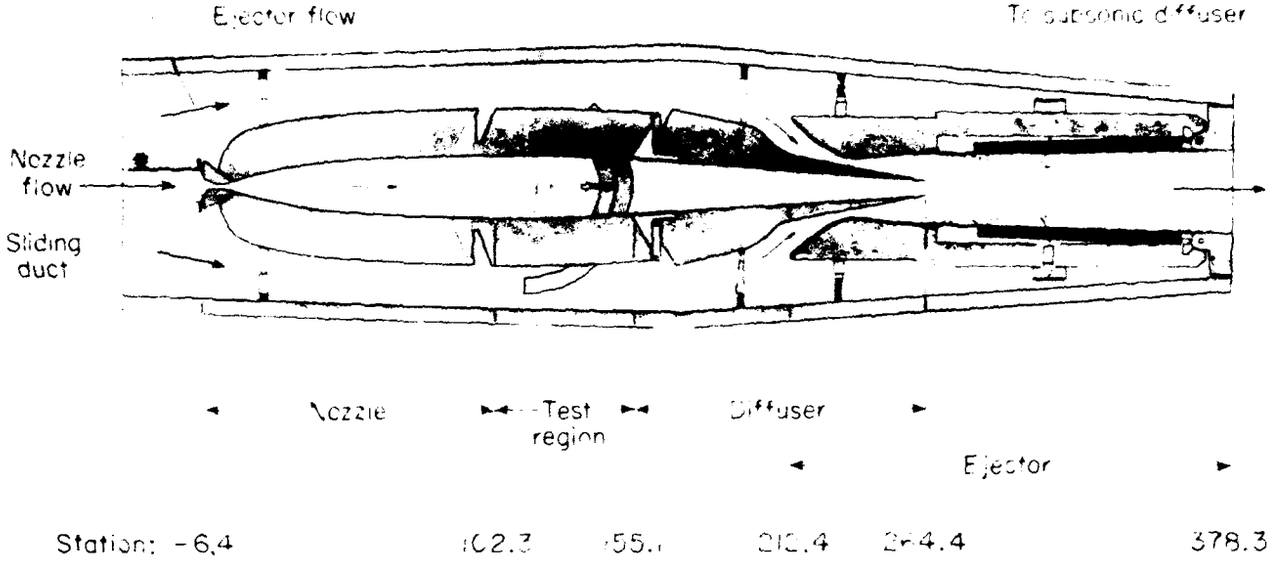


L-1716-A

The Langley hotshot tunnel is located in Building 1247B and is under the direction of the Aero-Physics Division. This tunnel is used for force and moment, pressure distribution, and heat-transfer-rate studies on reentry configurations. In addition, fundamental studies of high-energy flows can be made. Test medium can be nitrogen, air, or helium. Model mounting consists of a sting support. The conical nozzle has a 10° total angle. The nozzle throat is 0.025 to 0.5 inch in diameter. The test section, 24 inches in diameter with core 8 to 12 inches in diameter, exhausts into a vacuum chamber. The tunnel utilizes a pressure vessel or arc chamber to store the test gas precharged to elevated pressures. A bank of 720 capacitors charged to 7500 volts is capable of discharging 2×10^6 Joules to the test gas across a pair of electrodes in the arc chamber, increasing the potential temperature and pressure of the gas. This tunnel has been charged with helium and Mach numbers in the 60 range have been realized. Examples of operating conditions using nitrogen as the test medium are as follows:

Mach number	12 to 28
Stagnation pressure, psia	15 000
Stagnation temperature, $^{\circ}R$	5400
Reynolds number per foot	0.01×10^6 to 1.0×10^6
Running time, msec	1 to 120

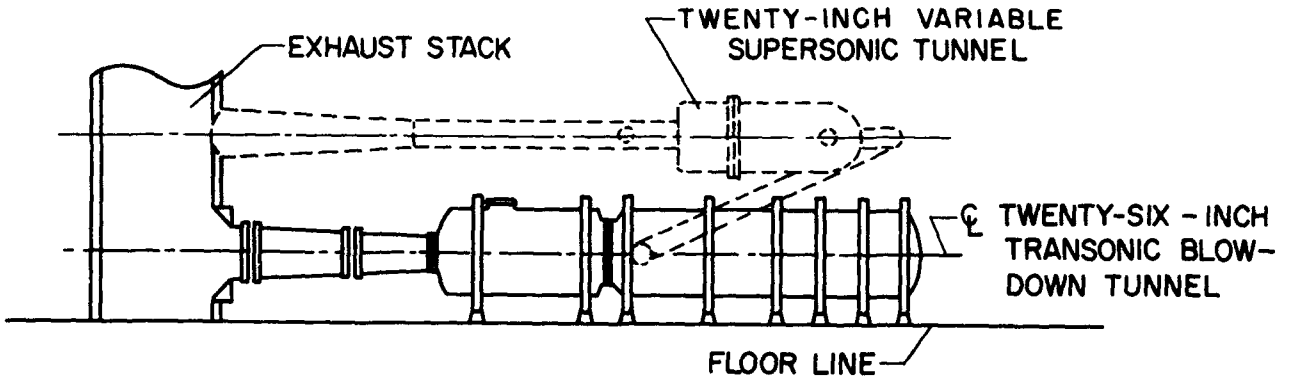
LANGLEY 2-FOOT HYPERSONIC FACILITY



The Langley 2-foot hypersonic facility is located in Buildings 640 and 641 and is under the direction of the Full-Scale Research Division. Test medium is air and is heated at higher Mach numbers by electrical resistance heater. Model mounting consists of a vertical sting and a side sting. Test section is 24 inches high, 24 inches wide, and 54 inches long. Facility is closed-circuit, ejector type with variable area throat. Examples of operating conditions are as follows:

Mach number	3.0	4.5	6.0
Stagnation pressure, psia	2.94 to 14.7	5.88 to 23.5	29.4 to 54.4
Stagnation temperature, $^{\circ}R$	540 to 530	610 to 960	760 to 960
Dynamic pressure, lb/sq ft	84 to 360	56 to 175	68 to 123
Reynolds number per foot	0.5×10^6 to 2.4×10^6	0.1×10^6 to 1.2×10^6	0.5×10^6 to 1.2×10^6
Running time	Continuous	Continuous	Continuous

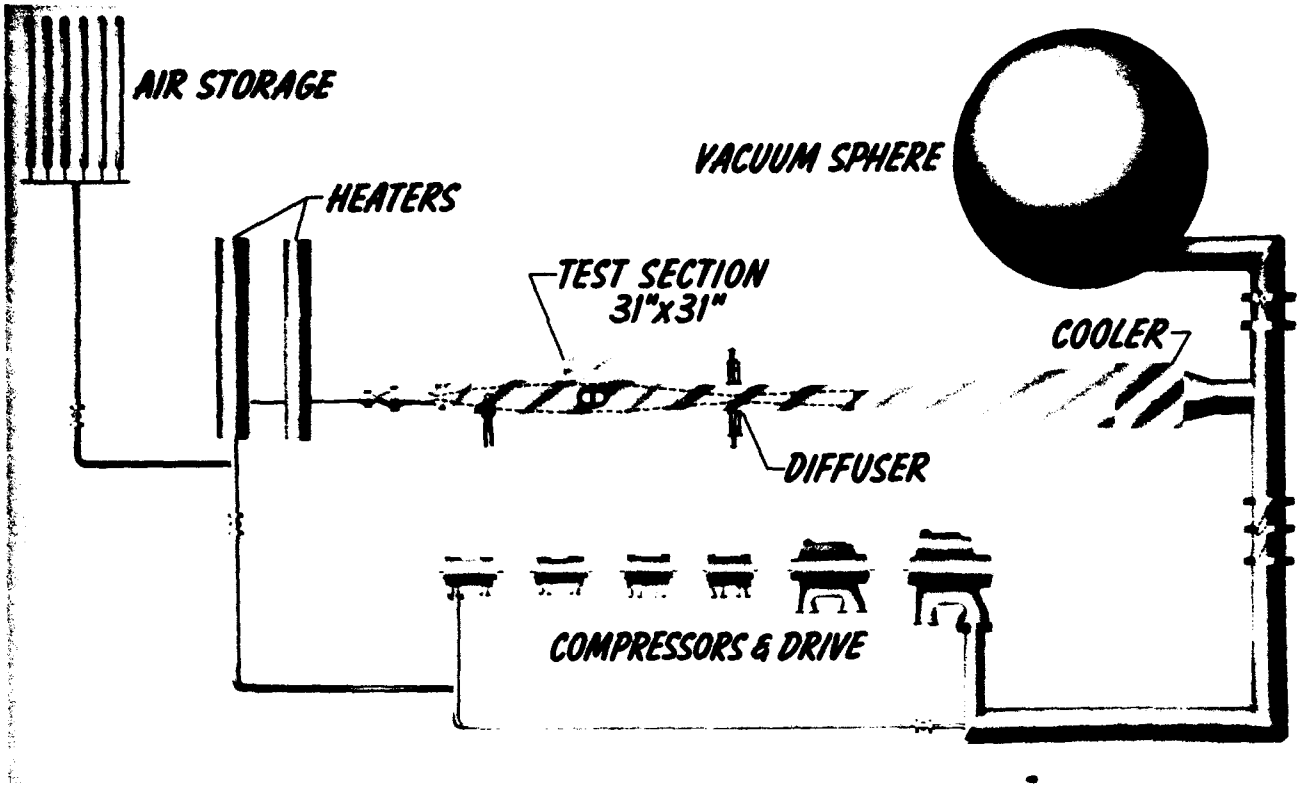
LANGLEY 26-INCH TRANSONIC BLOWDOWN TUNNEL



The Langley 26-inch transonic blowdown tunnel is located in Building 583 and is under the direction of the Full-Scale Research Division. The tunnel is primarily used for flutter tests of model configurations of aircraft components. The test medium is air. Model mounting consists of sting with circular-arc strut. Long fixed sting support is available for flutter investigations. Intermittent blowdown tunnel exhausts into atmosphere with independent control of Mach and Reynolds numbers. Octagonal slotted test section is 26 inches between flats. Examples of operating conditions are as follows:

Mach number	0.6 to 1.45
Stagnation pressure, psia	20 to 75
Stagnation temperature, ^{o}R	510 to 550
Reynolds number per foot	2.0×10^6 to 27.0×10^6
Running time (depending on Mach number and stagnation pressure), sec	20 to 50

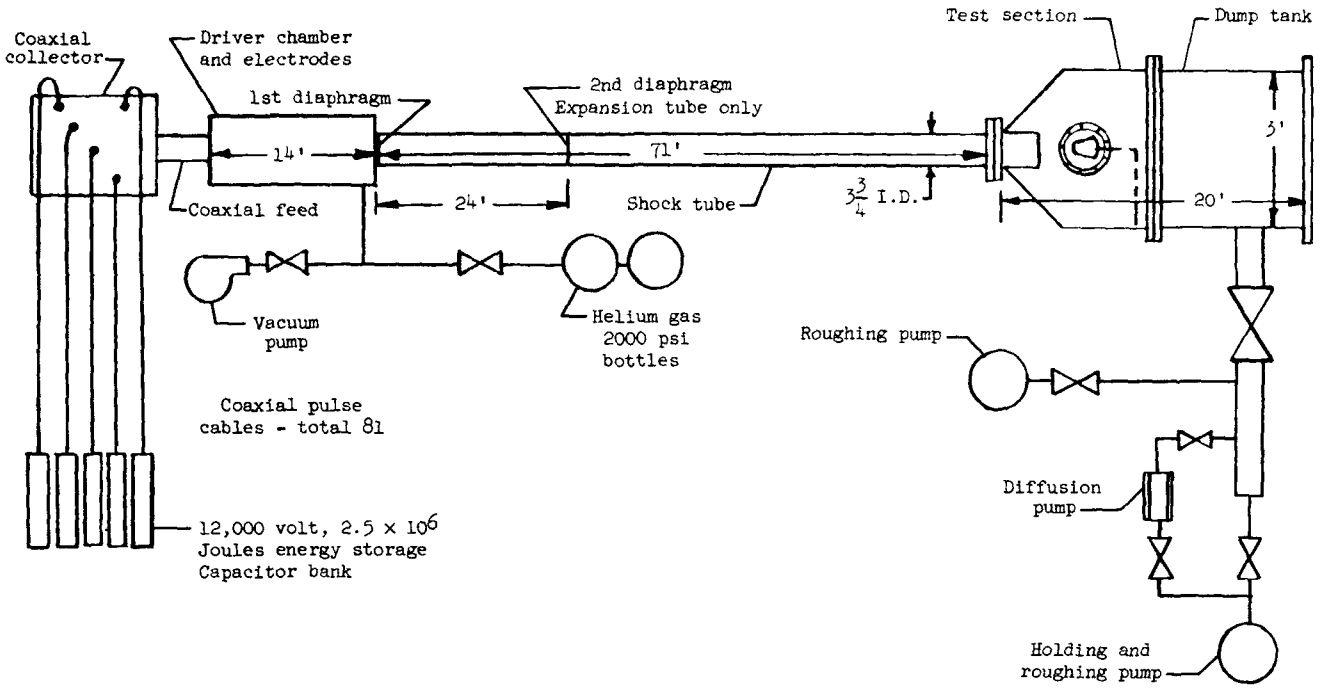
LANGLEY CONTINUOUS-FLOW HYPERSONIC TUNNEL



L-1990

The Langley continuous-flow hypersonic tunnel is located in Building 1251 and is under the direction of the Aero-Physics Division. This tunnel is used for heat-transfer and aerodynamic tests at Mach number 10 and Mach number 12. The test medium is air, heated by an electrical resistance heater. Model mounting allows for variable angles of attack and yaw on models up to 13 inches in span and 5 feet in length. There are two 31-inch-square interchangeable test sections for Mach number 10 and Mach number 12. The tunnel is closed circuit with vacuum tank for starting. Examples of operating conditions are as follows: Mach number 10 nozzle has been run over a pressure range from 15 to 100 atm (150 atm capability), at 1400° F and Reynolds numbers per foot from 0.5×10^6 to 1.7×10^6. At 26-atm pressure, the calibrated Mach number was 10.1, with a test core 14 inches square. The Mach number 12 nozzle has only been run blow-down (20-second run). At 60 atm and 1900° F, the calibrated Mach number was 11.9 with a test core of 9 inches.

LANGLEY PILOT MODEL EXPANSION TUBE



The Langley pilot model expansion tube (formerly called 36-inch hypersonic shock tunnel) is located in Building 1247G and is under the direction of the Aero-Physics Division. The name change reflects change in emphasis on type of experimental work being performed. The tunnel is currently being used to study expansion tube flows in air and other planetary atmospheres as preliminary work to that to be performed in the hot gas radiation research facility. The test medium is any gas. Energy is obtained from 2.5×10^6 Joule capacitor bank charged to 12,000 volts. The tube diameter is 4 inches. Facility can be operated in three modes: (1) expansion tube, (2) shock tube, and (3) shock tunnel. Examples of operating conditions are as follows:

Expansion tube:

Mach number	15 to 30
Running time, μsec	50 to 400
Stagnation enthalpy, Btu/lb	4500 to 18 000
Reynolds number per foot	10^5 to 10^6

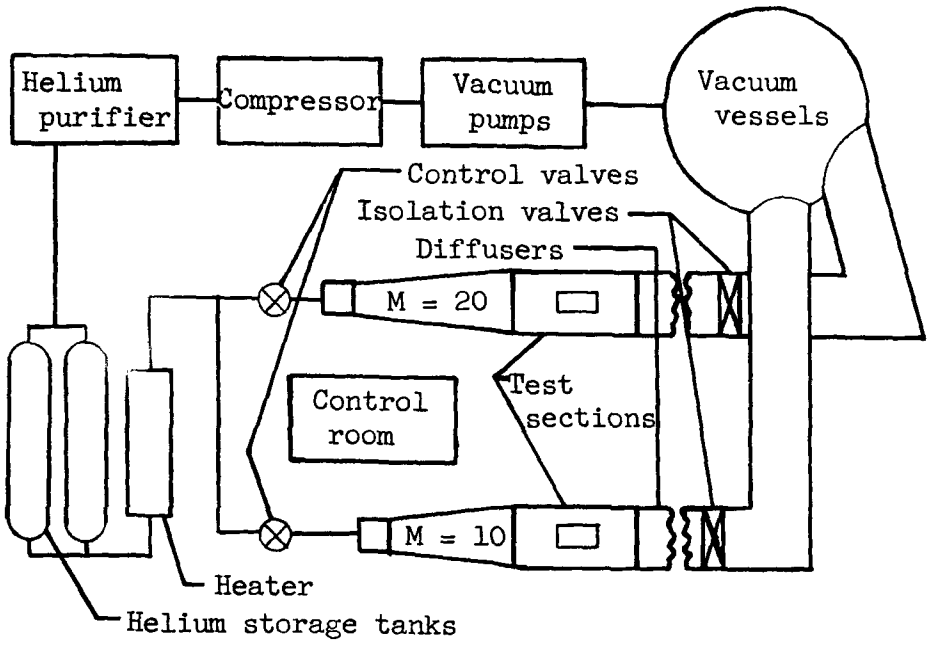
Shock tube:

Mach number	2 to 3
Running time, μsec	200 to 500
Stagnation enthalpy, Btu/lb	1700 to 9000
Reynolds number per foot	10^4 to 5×10^6

Shock tunnel:

Mach number	7 to 16
Running time, μsec	2000 to 5000
Stagnation enthalpy, Btu/lb	1700 to 9000
Reynolds number per foot	10^2 to 3×10^4

LANGLEY HYPERSONIC AEROELASTICITY TUNNELS

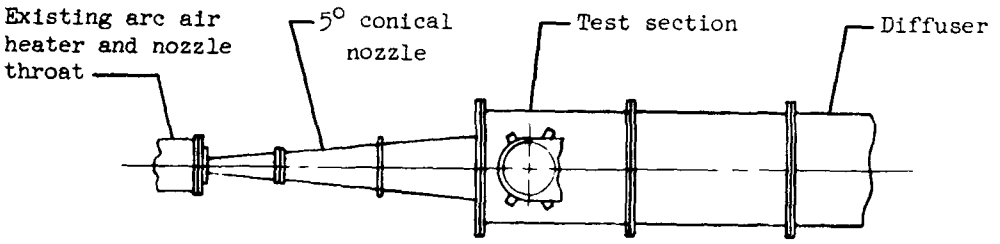


The Langley hypersonic aeroelasticity tunnels are located in Building 1247B and are under the direction of the Dynamic Loads Division. The tunnels are used for research and development of aeroelastic, thermal, and dynamic problems at hypersonic speeds. The test medium is helium, heated by a gas-fired storage-type heater. Model mounting consists of a sting; angle of attack of model can be changed during a run. Tunnels consist of two legs - Mach number 20 and Mach number 10 having axisymmetric contoured nozzles. Test-section diameter of Mach number 10 leg is 37 inches with 30-inch usable test core. Test-section diameter of Mach number 20 leg is 60 inches with 34-inch usable test core. It exhausts into a vacuum tank. Examples of operating conditions for each of the two legs are as follows:

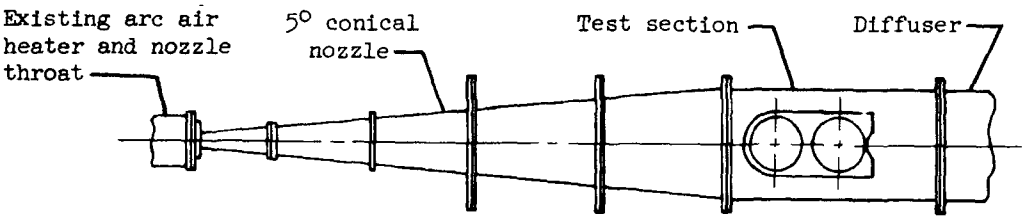
Mach number	10	20
Velocity, fps	5700 to 8190	5760 to 8280
Stagnation pressure, psia	100 to 4000	500 to 4000
Stagnation temperature, ^{o}R	540 to 1110	540 to 1110
Dynamic pressure, lb/sq ft	200 to 6900	100 to 920
Reynolds number per foot	0.6×10^6 to 57×10^6	1.0×10^6 to 18×10^6
Running time (maximum), sec	20	20

LANGLEY HYPERSONIC AEROTHERMAL DYNAMICS FACILITY

(4-FOOT HYPERSONIC ARC TUNNEL)



2-FOOT TEST SECTION

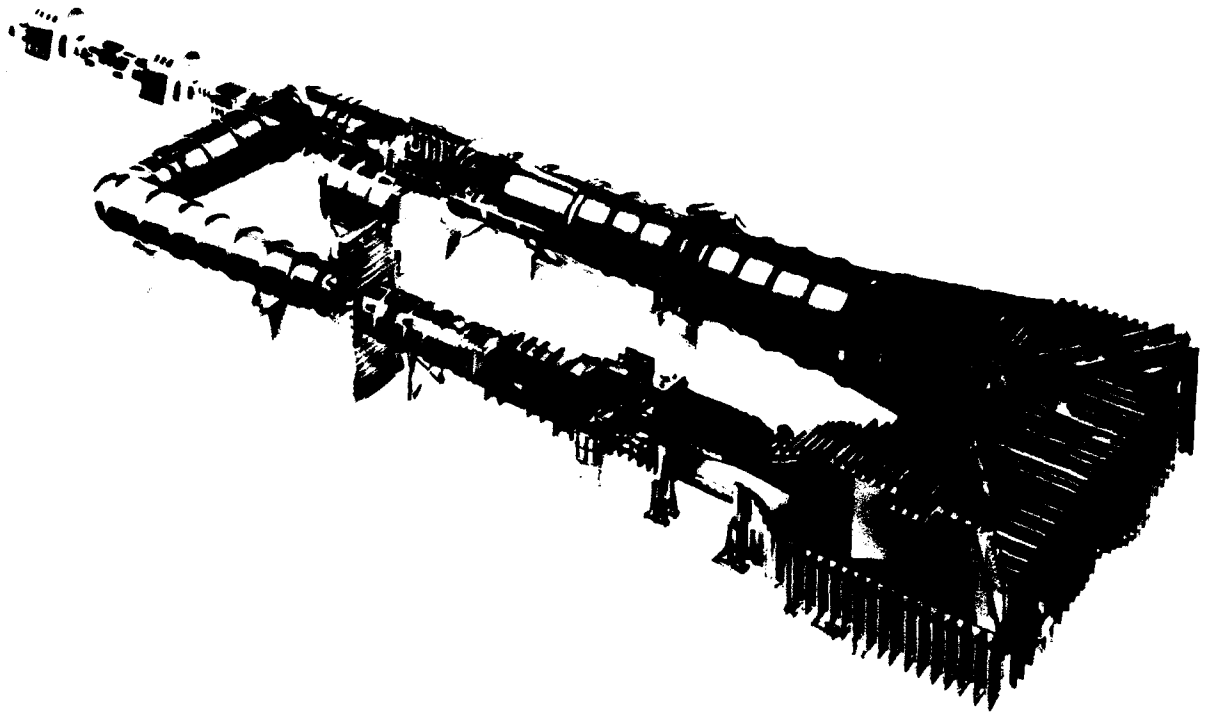


4-FOOT TEST SECTION

The Langley hypersonic aerothermal dynamics facility (4-foot hypersonic arc tunnel) is located in Building 1247B and is under the direction of the Aero-Physics Division. The tunnel is used for high-enthalpy hypersonic fluid mechanics research. The test medium is air and is heated by a 10- to 20-megawatt dc arc. Model mounting consists of model plunging apparatus with angle-of-attack capabilities. The nozzle is conical. The test-section diameters are 24 and 48 inches with maximum test core sizes of 12 and 24 inches, respectively. The tunnel exhausts into a 100-foot-diameter vacuum sphere. Examples of operating conditions are as follows:

Mach number	8 to 18
Stagnation pressure, psia	250 to 1500
Enthalpy, Btu/lb	1500 to 6000
Reynolds number per foot	1000 to 100 000
Diameter hemisphere, Btu/ft^2	120
Heating rate to 1 inch	
Maximum model size:	
Blunt model diameter, in.	3 to 6
Slender model diameter, in.	5 to 9
Length (maximum), ft	2 to 4

LANGLEY 4- BY 4-FOOT SUPERSONIC PRESSURE TUNNEL

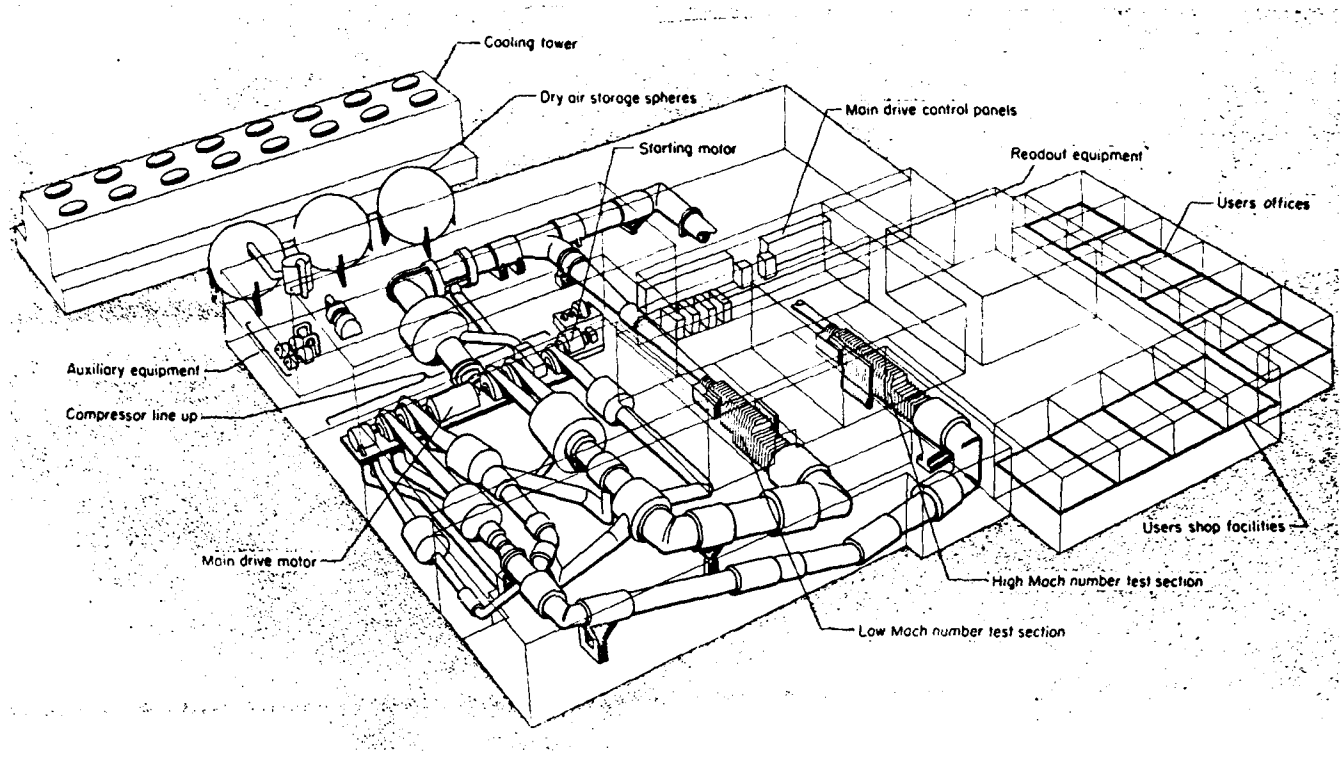


L-60681

The Langley 4- by 4-foot supersonic pressure tunnel is located in Building 1236 and is under the direction of the Full-Scale Research Division. This tunnel is used for force, moment, and pressure studies. The test medium is air. Model mounting consists of various sting arrangements, axial and lateral movement are available, and side-wall support. Tunnel is continuous flow, variable pressure with interchangeable nozzle blocks. The test section is 4.5 feet square and 7 feet long. Examples of operating conditions are as follows:

Mach number	1.25 to 2.6
Stagnation pressure, psia	4 to 30
Stagnation temperature, ^{o}R	570
Dynamic pressure, lb/sq ft	250 to 1368
Reynolds number per foot	1.4×10^6 to 6.6×10^6

LANGLEY UNITARY PLAN WIND TUNNEL

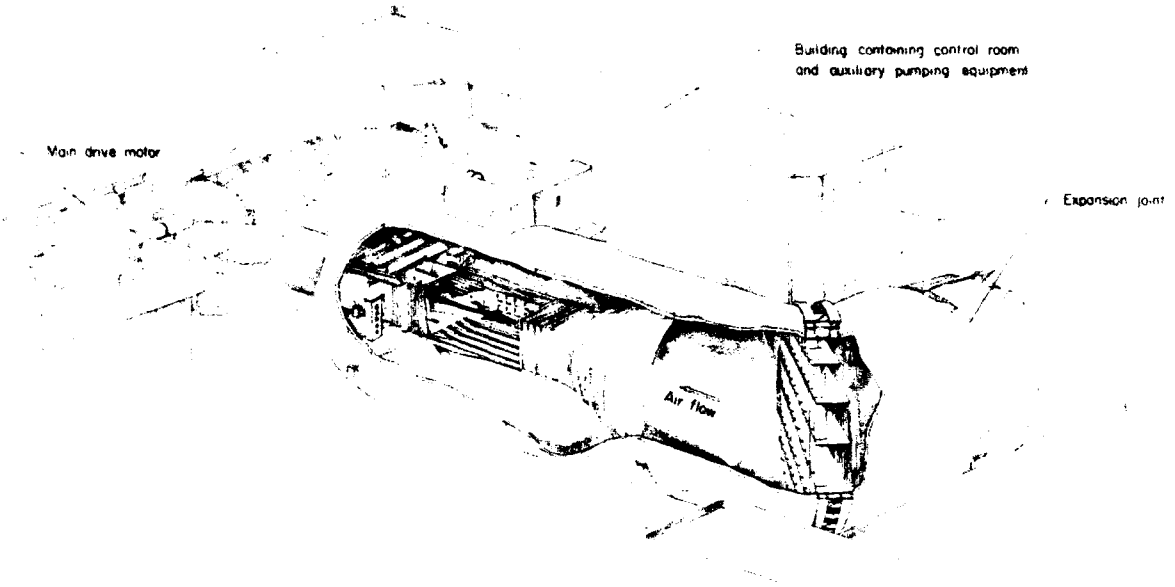


The Langley Unitary Plan wind tunnel is located in Building 1251 and is under the direction of the Full-Scale Research Division. The tunnel is used for force, moment, pressure-distribution, and heat-transfer studies. The test medium is air. Model mounting consists of various sting arrangements: axial and lateral movement and side-wall support. The tunnel is of the continuous-flow, asymmetric sliding-block type. There are two test sections, each 4 feet square and 7 feet long. Examples of nonoverload operating conditions for the two test sections are as follows:

Test section number 1:		
Mach number	1.47	to 2.86
Stagnation pressure, psia	4.0 to 30.0	4.0 to 50.9
Dynamic pressure, lb/sq ft	250 to 1860	110 to 1400
Reynolds number per foot	1.04×10^6 to 7.83×10^6	0.56×10^6 to 7.10×10^6
Test section number 2:		
Mach number	2.29	to 4.63
Stagnation pressure, psia	4.0 to 29.4	15.0 to 142
Dynamic pressure, lb/sq ft	170 to 1260	95 to 905
Reynolds number per foot	0.76×10^6 to 5.57×10^6	0.82×10^6 to 7.78×10^6

The normal operating temperature is approximately 150° F with heat bursts of 300° F to 400° F available for heat-transfer studies.

LANGLEY 8-FOOT TRANSONIC PRESSURE TUNNEL

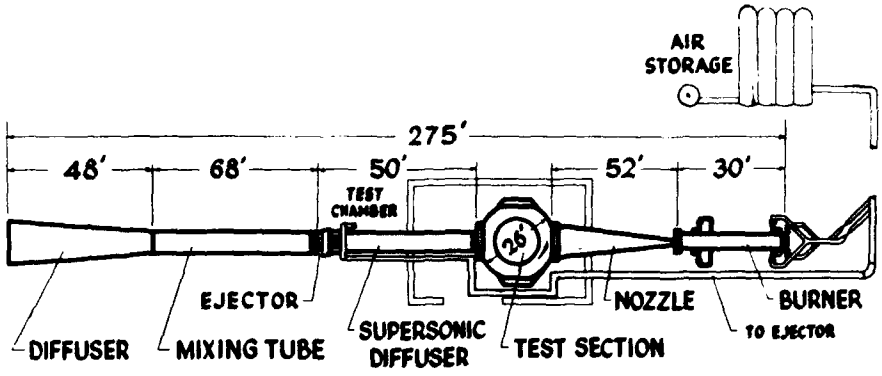


L-57-2529

The Langley 8-foot transonic pressure tunnel is located in Building 640 and is under the direction of the Full-Scale Research Division. The test medium is air. The tunnel has a sting-type model support system with tunnel wall mounts available. It is a single-return closed-circuit tunnel with Mach number continuously variable from 0.2 to 1.3. Stagnation pressure, stagnation temperature, and dewpoint temperature are controlled. Test section is 7.1 foot square. Examples of operating conditions are as follows:

Mach number	0.2 to 0.3	0.4 to 1.0	1.03 to 1.2	1.3
Stagnation pressure, atm	0.25 to 2.0	0.25 to 1.7	0.25 to 1.4	0.25 to 1.0
Stagnation temperature, $^{\circ}R$	580	580	580	580
Dynamic pressure, lb/sq ft	14 to 250	53 to 1333	203 to 1232	226 to 906
Reynolds number per foot	0.3×10^6 to 3.6×10^6	0.6×10^6 to 7.0×10^6	1.0×10^6 to 5.9×10^6	1.0×10^6 to 4.2×10^6

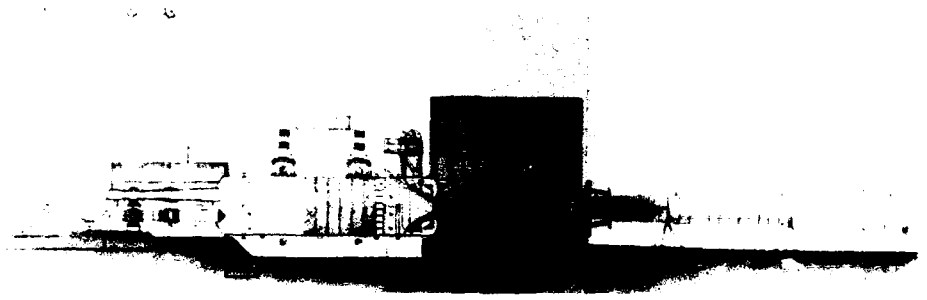
LANGLEY 8-FOOT HIGH-TEMPERATURE STRUCTURES TUNNEL



The Langley 8-foot high-temperature structures tunnel is located in Building 1265 and is under the direction of the Structures Research Division. This tunnel is used for structures studies and the study of thermal protection for hypersonic flight. The test medium is hydrocarbon fuel-air combustion gases. Heat is provided by hydrocarbon air combustion and oxygen enrichment is required for 4500° R. Model mounting is semispan or sting. The tunnel has an axisymmetric, fixed-geometry nozzle with a throat diameter of 5.62 inches, and the test-section diameter is 96 inches. It exhausts through a diffuser into the atmosphere. Examples of operating conditions are as follows:

Stagnation pressure, psia	200	200	4000	4000
Stagnation temperature, °R	2500	4500	2500	4500
Enthalpy, Btu/lb	730	1400	730	1400
Mach number	7.7	6.8	7.7	6.8
Velocity, fps	5360	7930	5360	7930
Static pressure, psia	0.018	0.022	0.36	0.44
Static temperature, °R	215	585	215	585
Static density, slug/cu ft	0.061×10^{-4}	0.034×10^{-4}	1.2×10^{-4}	0.68×10^{-4}
Dynamic pressure, lb/sq ft	103.5	103.5	2075	2075
Reynolds number per foot	0.2×10^{6}	0.06×10^{6}	3.7×10^{6}	1.5×10^{6}
Weight flow, lb/sec	47	36	932	715
Running time, sec	210	220	30	42
Maximum model diameter for -				
Blunt body, in.	24	24	24	24
Streamlined body, in.	40	40	40	40

LANGLEY 9- BY 6-FOOT THERMAL STRUCTURES TUNNEL



L-331-A

The Langley 9- by 6-foot thermal structures tunnel is located in Building 1256 and is under the direction of the Structures Research Division. This tunnel is used primarily for studies of aerodynamic heating and loading. Test medium is air, heated by a metallic-mass heat exchanger. Model mounting consists of sting, floor, or panel mounts. The tunnel has a supersonic two-dimensional contoured nozzle with test section 72 inches by 105 inches and exhausts through diffuser into atmosphere. Examples of operating conditions are as follows:

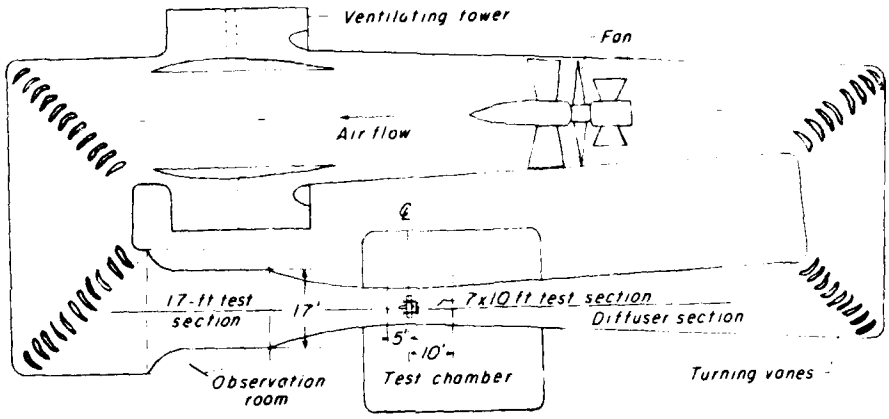
Stagnation pressure, psia	50	50	200	200
Stagnation temperature, $^{\circ}R$	760	1120	760	1120
Enthalpy, Btu/lb	190	285	190	285
Mach number	3	3	3	3
Velocity, fps	2420	2940	2420	2940
Static pressure, psia	1.36	1.36	5.44	5.44
Static temperature, $^{\circ}R$	270	400	270	400
Static density, slug/cu ft	4.34×10^{-4}	2.83×10^{-4}	16.8×10^{-4}	11.3×10^{-4}
Dynamic pressure, lb/sq ft	1230	1230	4940	4940
Reynolds number per foot	4.85×10^{6}	2.9×10^{6}	18.4×10^{6}	10.6×10^{6}
Weight flow, lb/sec	1680	1380	6720	5520
Running time, sec	60	75	15	18
Maximum model diameter:				
Blunt body, in.	33	33	33	33
Streamlined body, in.	47	47	47	47

The 9- by 6-foot thermal structures tunnel (with hot core) is used primarily for studies of aerodynamic heating and loading. The test medium is air plus combustion products, heated by gas-fired central core. Model mounting

consists of sting, floor, or panel mounts. The tunnel has a supersonic two-dimensional contoured nozzle with test section 48 inches by 72 inches and exhausts through the diffuser into the atmosphere. Examples of operating conditions are as follows:

Stagnation pressure, psia	50	200
Stagnation temperature, $^{\circ}$ R	2500	2500
Enthalpy, Btu/lb	760	760
Mach number	3	3
Velocity, fps	4392	4392
Static pressure, psia	1.36	5.44
Static temperature, $^{\circ}$R	893	893
Static density, slug/cu ft	1.27×10^{-4}	5.09×10^{-4}
Dynamic pressure, lb/sq ft	1240	4960
Reynolds number per foot	0.5357×10^{6}	2.143×10^{6}
Weight flow, lb/sec	1198	4792
Running time, sec	75+	25+
Maximum model diameter:		
Blunt body, in.	33	33
Streamlined body, in.	47	47

LANGLEY 300-MPH 7- BY 10-FOOT TUNNEL

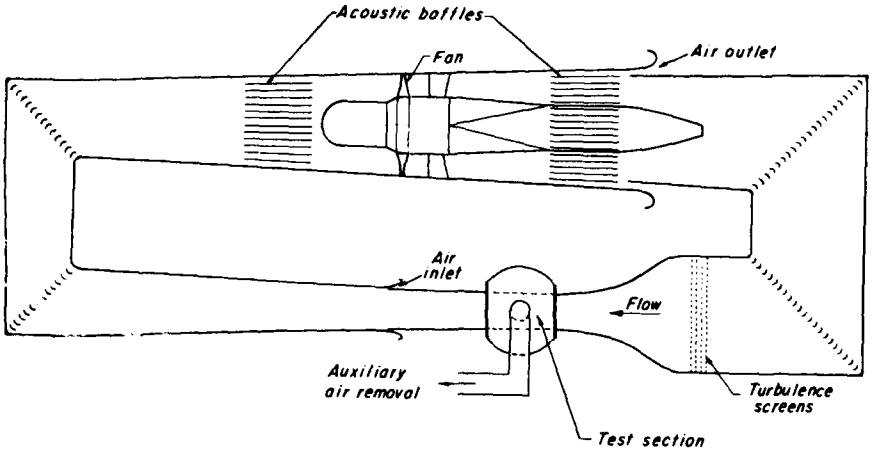


The Langley 300-MPH 7- by 10-foot tunnel is located in Building 1212A and is under the direction of the Full-Scale Research Division.

7- BY 10-FOOT TEST SECTION: Speed is variable from 0 to 300 mph in this continuous-flow, fully closed test section. The stagnation pressure and temperature are atmospheric. The tunnel Reynolds number per foot ranges from 0 to 2.5×10^6. Model support systems include semispan, sting, and strut. The test section is 15 feet long.

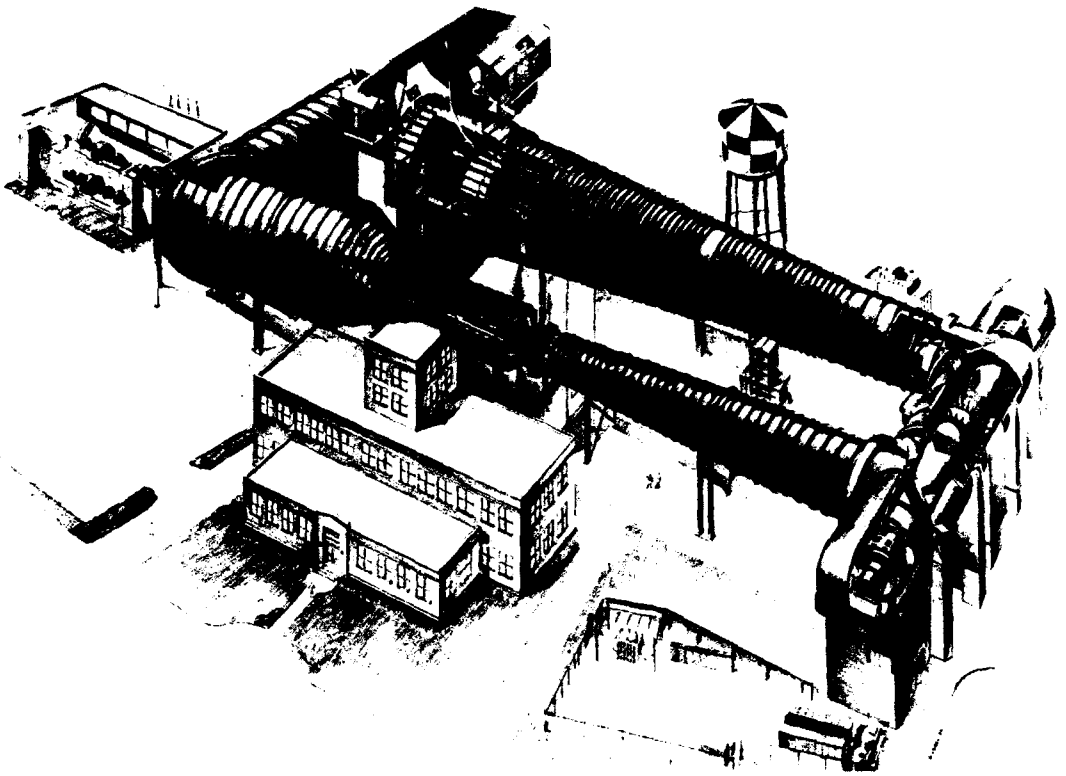
17-FOOT TEST SECTION: Speed is variable from 0 to 80 mph in this continuous-flow test section which is 17 feet wide and 15.8 feet high. A moving belt can be installed for ground-effects tests. Tunnel stagnation pressure and temperature are atmospheric. Tunnel Reynolds number per foot ranges from 0 to 0.7×10^6. Model support systems include semispan and sting. Test section is 15 feet long. This section is designed to test V/STOL models through high angles of attack with minimum tunnel wall effects.

LANGLEY HIGH-SPEED 7- BY 10-FOOT TUNNEL



The Langley high-speed 7- by 10-foot tunnel is located in Building 1212B and is under the direction of the Full-Scale Research Division. This continuous-flow, subsonic, atmospheric wind tunnel can supply speeds in excess of Mach number 0.90. Transonic operation is available by connection to the 35,000 horsepower compressor of the Langley 16-foot transonic tunnel. Model mounting consists of sting support system, forced rolling apparatus, and side-wall turntable. The test section is 79 inches high and 115 inches wide with 60 inches as the usable length for subsonic operation and 120 inches as the usable length for transonic operation. In the closed test section at Mach number 0.95, the Reynolds number per foot is 4.0×10^6. In the transonic test section at Mach number 1.20, the Reynolds number per foot is 4.2×10^6.

LANGLEY 16-FOOT TRANSONIC TUNNEL

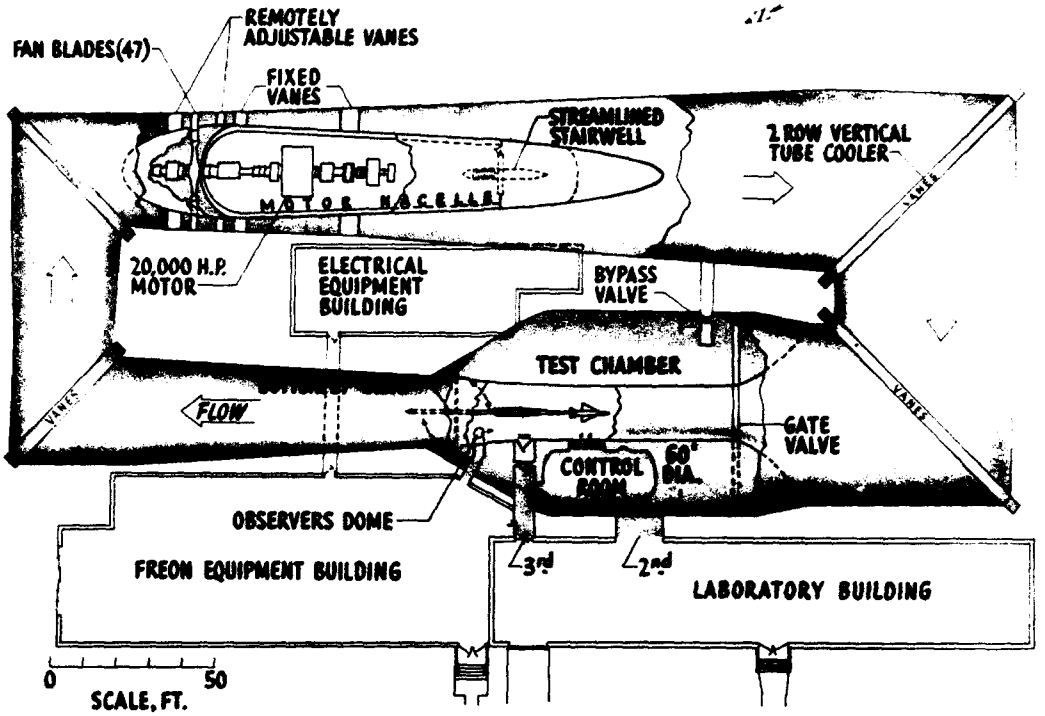


L-88143.1

The Langley 16-foot transonic tunnel is located in Building 1146 and is under the direction of the Full-Scale Research Division. The test medium is air with air exchange for cooling. Model mounting consists of wall, sting, and strut supports. This is a continuous, single-return, atmospheric tunnel with slotted octagonal throat and test section which is 15.5 feet wide and 22 feet long. It can be used for propulsion tests with 90 percent hydrogen peroxide or compressed air. Examples of operating conditions are as follows:

Stagnation pressure	Atmospheric
Stagnation temperature, ^{o}R	510 to 650
Reynolds number per foot	1.2×10^{6} to 3.7×10^{6}
Mach number	0.2 to 1.3
Dynamic pressure, lb/sq ft	58 to 830

LANGLEY TRANSONIC DYNAMICS TUNNEL

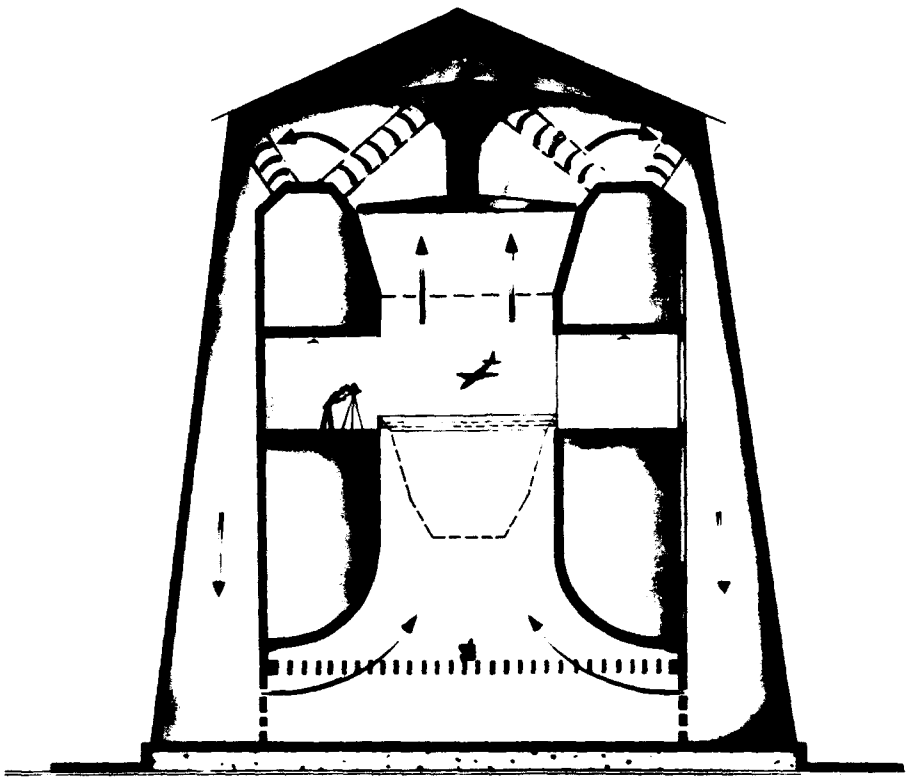


L-907

The Langley transonic dynamics tunnel is located in Building 648 and is under the direction of the Dynamic Loads Division. The test medium is air or Freon-12. The tunnel is used for investigation of flutter, buffeting, vortex shedding, gust loads, and other dynamic characteristics. Model mounting consists of sting, floor, wall, and cable supports. This is a closed-circuit, single-return tunnel with a test section 16 feet square. There is a 30-foot uniform flow region at subsonic speeds and a 20- to 12-foot uniform flow region through the transonic range. Examples of operating conditions are as follows:

Mach number	0 to 1.22
Stagnation pressure, psia	0.1 to 14.7
Stagnation temperature, $^{\circ}R$	Ambient to 600
Reynolds number per foot (maximum):	
Freon-12	8.5×10^6
Air	3.5×10^6
Dynamic pressure (maximum), lb/sq ft:	
Freon-12	420
Air	360

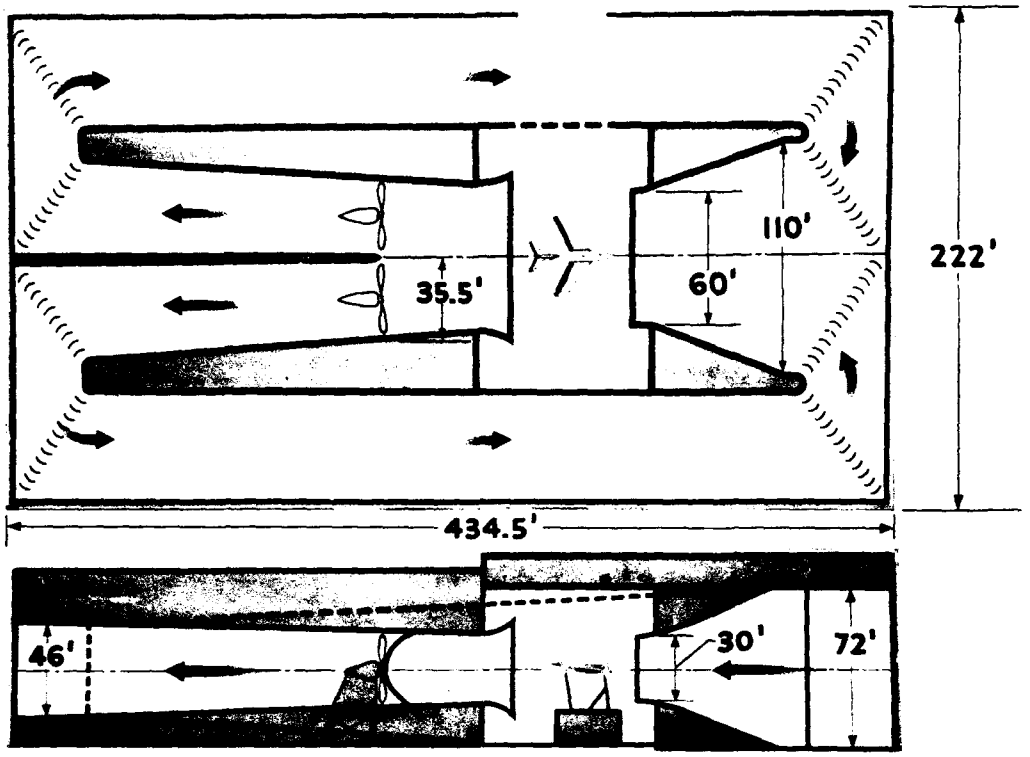
LANGLEY SPIN TUNNEL



L-86258

The Langley spin tunnel is located in Building 645 and is under the direction of the Flight Mechanics and Technology Division. This tunnel is used to investigate spin characteristics of dynamically scaled models. The test medium is air. The test section is vertical with 12 sides, 20 feet across the flats. The length of the vertical test section is 25 feet with a closed throat and annular return passage. Tunnel speed is variable from 0 to 90 fps with accelerations to 15 ft/sec^2 and decelerations to 25 ft/sec^2. Stagnation pressure is atmospheric, turbulence factor is 2, and Reynolds number per foot is 0 to 0.62×10^6.

LANGLEY FULL-SCALE TUNNEL



L-60681

The Langley full-scale tunnel is located in Building 643 and is under the direction of the Flight Mechanics and Technology Division. The test region of the tunnel is 30 feet high, 60 feet wide, and 56 feet long. The tunnel is a continuous, double-return type with an open throat. The test airspeed range is from 25 to 110 mph in 24 steps; a separate speed control is available permitting a continuous airspeed variation from 0 to approximately 40 mph. A reflection-plane floor 42 feet wide and 32 feet long can be installed for full-scale semispan-wing investigations. The tunnel is equipped for free-flight dynamic model studies. Shielded struts are available for model support. Examples of operating conditions are as follows:

Mach number	0 to 0.14
Stagnation pressure	Atmospheric
Stagnation temperature	Ambient
Reynolds number per foot	0 to 1×10^6
Dynamic pressure, lb/sq ft	0 to 30
Maximum model size:	
Span, ft	50
Weight, lb	15 000
Wing semispan, ft	20

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., June 2, 1965.

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2. Anon.: National Wind-Tunnel Summary. NASA and Dept. Defense, July 1961. (Available from Clearinghouse, U.S. Dept. Com.)

3. Anon.: Manual for Users of the Unitary Plan Wind Tunnel Facilities of the National Advisory Committee for Aeronautics. NACA, 1956.